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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

August, 1947

New station of the Illinois Power Company at Havana, Illinois which opened in July with an initial capacity of 80,000 kw

Five Years Performance of Paper Mill Unit ▶

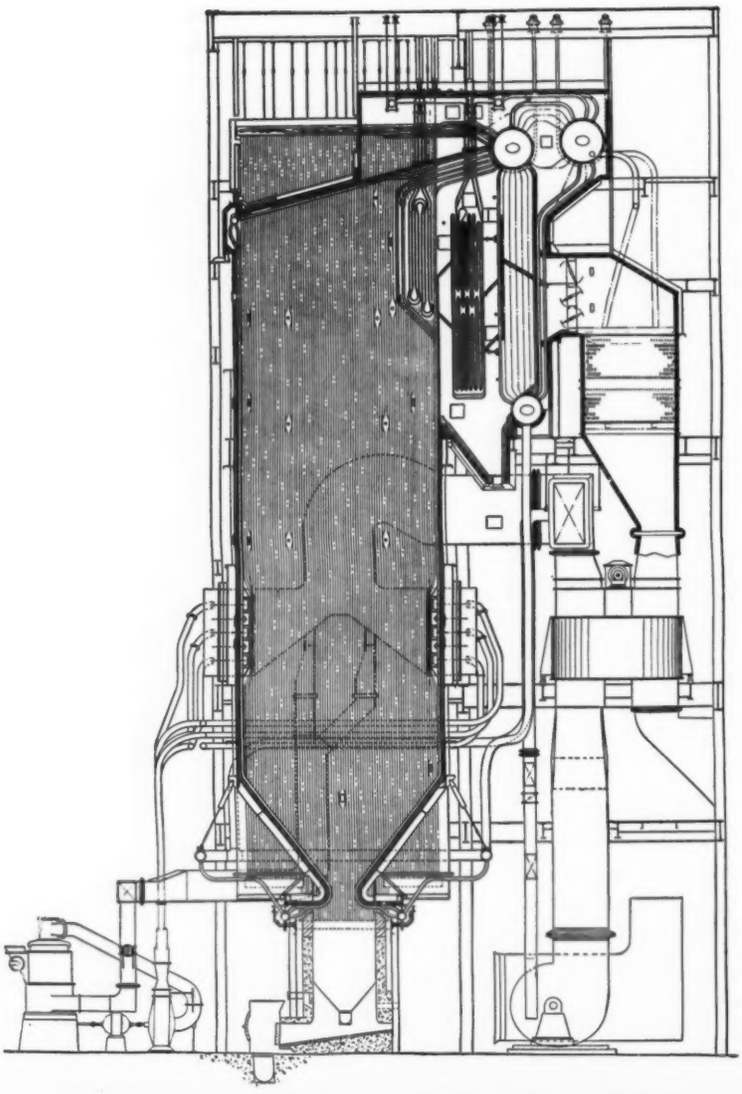
Quick Starting of High-Pressure Steam Turbine Units ▶

Work of Fuel Research Station in Study of Boiler Deposits ▶

Recent C-E Steam Generating Units for Utilities

O. H. HUTCHINGS STATION

THE DAYTON POWER & LIGHT COMPANY



THE C-E Unit illustrated here is one of two such units now in process of fabrication for the O. H. Hutchings Station of The Dayton Power & Light Company at Dayton, Ohio.

The installation will be of the Semi-Outdoor Type.

Each unit is designed to produce, at maximum continuous output, 500,000 lb of steam per hr at 1350 psi and a total temperature of 950 F.

The units are of the 3-drum type with 2-stage superheaters. Furnaces are fully water cooled with closely spaced plain tubes and are of the basket-bottom type. C-E Economizers and Ljungstrom Air Heaters follow the boiler surface.

Pulverized coal firing is used employing C-E Raymond Bowl Mills and Vertically-Adjustable, Tangential Burners. This burner arrangement, in conjunction with Montaup-type by-pass dampers, assures accurate control of superheat temperatures.

B-148

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C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS; ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINETEEN NUMBER TWO

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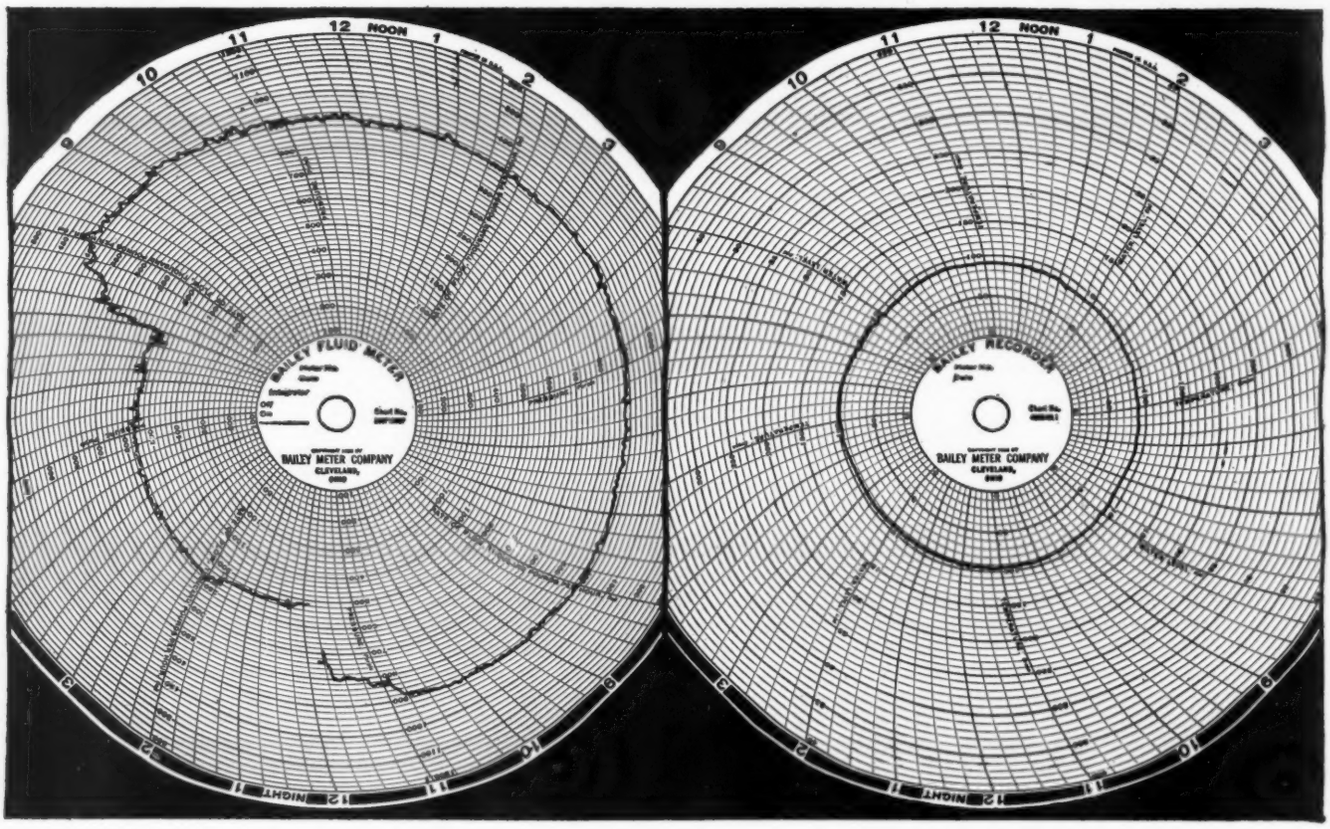
SOUTHERN STATION REPORTS

level held within plus-or-minus ½-inch



YOU couldn't ask for much closer water level control than is indicated by these charts from a well-known Southern utility station. With a load range of from 200,000 to 430,000 pounds of steam per hour, extreme limits of drum-level variation are no more than plus-or-minus one-half inch.

The steam generator is one of two Combustion Engineering three-drum units in this station. Each has a rated capacity of 425,000 pounds of steam an hour, delivered from the superheater outlet at 860 psi and 835 degrees F. Equally close water level control is obtained on both high-duty units, which are equipped with two-element COPES Flowmatics.

The complete story is told in Bulletin 469, a 16-page performance report on COPES Flowmatic in this and two other stations of the same utility system. Illustrated with plant photographs, sectional views of the boilers and charts, this informative report is yours for the asking. Write for it.

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Feed Water Regulators, Pump Governors, Differential Valves, Liquid Level Controls, Reducing Valves and Desuperheaters

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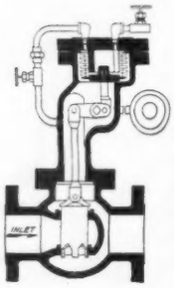

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COPES Differential Valves maintain constant pressure drop across the feed water regulator valves, regardless of changes in pump pressure or line friction losses accompanying wide fluctuations in boiler load. Individually designed for each installation. Available in separate bodies, as illustrated, or in combination with the feed water regulator valve bodies.

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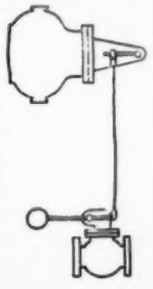
For control of water or steam input or output, open or closed vessels. For throttling steam supply to fluid pumps. Semi-steel, cast-steel or forged-steel float chambers, with floats of different sizes and materials to meet individual needs. The direct- or relay-operated COPES Valves have low friction, high lift, accurate balance, ports designed for each installation.



EDITORIAL

A Consumer Dilemma

The recent wage agreement in the coal industry coupled with impending shortages of petroleum products due to increased demand for all forms of oil have put the squeeze on the consumer. In normal times a gradual switch from coal for heating, if for convenience alone, is to be expected.

Uncertainties of a few months back in the coal industry affecting supply and ultimate cost to the consumer served to accelerate the demand for other fuels. Since the supply of gas for heating in the Eastern United States was far from adequate, oil was looked to for the solution.

A recent editorial appearing in these pages told how oil users were facing curtailment due to shortages and of increases in the price of fuel oil to discourage its use. One of the large oil companies has just announced an increase in its price of several petroleum products to protect the fuel oil supply of its customers against the added competition of those who might be tempted to convert from coal to oil on the basis of sheer economics. It is again made apparent that the petroleum industry cannot now handle any sharply increased demand for fuel oil despite the fact that we are now importing oil from the Middle East.

Although the recent boosts in coal prices have created an unbalanced price situation extremely favorable to oil, a large segment of domestic users will have to string along with coal. That coal has not lost appreciable ground is shown by a recent report of the Anthracite Institute indicating that the use of hard coal for heating in New England and the Middle Atlantic states had increased 2,100,000 tons a year since 1940. Part of this increase can be attributed to the greater occupancy of housing facilities.

It is probable that despite increases in the price of fuel oil, even to the point where coal is definitely more economical, demand for oil will not slacken as many small users will be willing to pay for the convenience plus the added cost of conversion. However, it appears that the position of coal for heating purposes will remain strong.

The foregoing will have little bearing, however, on action to be taken in industry other than to accentuate the scarcity of the lighter fuel oils; for in the industrial field the economic aspects usually outweigh any consideration of convenience.

Meeting Increasing Power Demand

Proponents of further federal hydro development received little encouragement when the Congress adjourned without taking action on pending St. Lawrence legislation; in its substantial trimming of the Interior Department's power budgets; and in turning over to the Army Engineers appropriations for flood control in the Southwest without reference to establishment of a Missouri River Power Authority. However, funds were provided for a substantial increase in capacity at Grand Coulee and some other Reclamation Bureau projects fared rather well. This department received the major portion of all the power appropriations amounting to over ninety-three million dollars. Many of the more drastic cuts made by the House were partly restored by the Senate and a compromise resulted in the Conference Committee.

The ever-increasing power demand has now not only reached an all-time seasonal peak, but has passed the wartime winter peak. This fact has been cited by some public power advocates as pointing to an impending power shortage. However, authoritative sources within the electric utility industry give assurance that, although reserve capacity is still low, no actual power shortage is to be anticipated. There is between nine and ten million kilowatts of new steam capacity now on order of which it is estimated nearly two million will have gone into service by the end of the current year. Presumably, the rate at which new capacity is added will take care of increasing load and gradually build up the reserve, except perhaps in isolated cases. Even there the extensive interconnection fostered by the war should obviate most local shortages.

It is likely that St. Lawrence power, tied in as it is with a seaway project, may eventually materialize, perhaps as a self-liquidating project, especially as it now appears to have bipartisan support in Congress. The essential fact, however, is that the immediate situation could not be altered by more federal hydro projects as they would take much longer to construct than steam capacity. Excluding unforseen events, the long-range program of extension put into effect by the utilities since the war is calculated to meet fully the normal increase in electric demands.

Five Years Performance of Minnesota Paper Mill Steam Generating Unit

By A. S. OLIVER
Supt. of Steam Power,
Minnesota & Ontario Paper Co.

During periods of 432, 357 and 346 days of continuous operation at from 200 to 230 per cent rating, overall efficiencies ranged from 83 to 86 per cent on this 90,000-lb-per-hr unit generating steam at 450 psi, 600 F. Pulverizing cost, including power and maintenance labor and material, averaged 4.4 cents per ton over a period of five years.

IN 1941 the boiler plant of the Minnesota & Ontario Paper Company at International Falls, Minn., contained five C-E Heine-type four-drum boilers, each rated at 90,000 lb of steam per hr at 450 psi, 580 F, and two 15,000-lb per hr Erie City two-drum units designed for 150 psi, 430 F steam. Each of the five larger units was served by two Strong-Scott pulverizers and the two smaller units were fired with Riley stokers.

Plans for extension of power facilities resulted in the installation, early in 1942, of a 90,000-lb per hr C-E two-drum Type VU steam generator to operate at the same pressure and steam temperature as the larger existing boilers. This new unit had a completely water-cooled furnace, a tubular air heater and was fired by four horizontal turbulent burners, supplied with pulverized coal by two C-E Raymond bowl mills. The mill capacity of 7400 lb per hr each was based on coal having a 100 Hardgrove grindability and grinding to a fineness of 80 per cent through a 200-mesh screen when containing 5 per cent moisture. Each mill was driven by a 60-hp motor. The

Aerial View of Minnesota & Ontario Paper Company's Mill; plant on right is on American side of the International Border where this equipment is installed

unit was guaranteed to handle outputs from 40,000 to 90,000 lb per hr under the conditions listed in Table 1.

Other equipment accompanying the new unit included a 53,000-cfm Clarage induced-draft fan, motor-driven at variable speed through a magnetic coupling; a 29,000-cfm constant-speed Clarage forced-draft fan, the air supply through the inlet louvre being controlled by a Hagan combustion control power cylinder; motor-driven six-stage Ingersoll-Rand boiler feed pumps of 350 gpm capacity at 1260 ft head; Diamond soot blowers, Edward feed and check valves and Copes feedwater regulator.

TABLE 1—PERFORMANCE GUARANTEES

Evaporation, lb per hr	40,000	85,000	90,000
Feedwater temp, deg F	218	218	218
Press. at superheater outlet, psi	435	435	435
Press. drops through superheater, lb	2.5	9.0	10.0
Total steam temp, deg F	560	580	581
Overall efficiency, per cent	84.9	85.2	85.0
Fuel fired, 16 per hr	3,630	7,750	8,240
Draft loss through boiler and superheater, in. H_2O	0.37	1.66	1.89
CO_2 leaving boiler, per cent	14.3	15	15
Boiler exit gas temp, deg F	532	640	650
Combustion rate, Btu per cu ft per hr	11,350	24,200	25,750
Gas through air heater, lb per hr	53,300	109,300	116,300
Air through air heater, lb per hr	34,400	84,000	90,100
Temp of gas entering air heater, deg F	532	640	650
Temp of gas leaving air heater, deg F	351	403	409
Temp of air leaving air heater, deg F	397	424	428
Temp of air entering air heater, deg F	100	100	100
Draft loss through air heater (air side), in. H_2O	0.52	2.32	2.70
Draft loss through air heater (gas side), in. H_2O	0.44	1.74	1.89

On the Bailey Meter boiler panel are mounted a steam flow-air flow recorder, an integrating and recording feedwater meter, a water level recorder, temperature recorders, multipoint draft gage, pressure gages, etc.

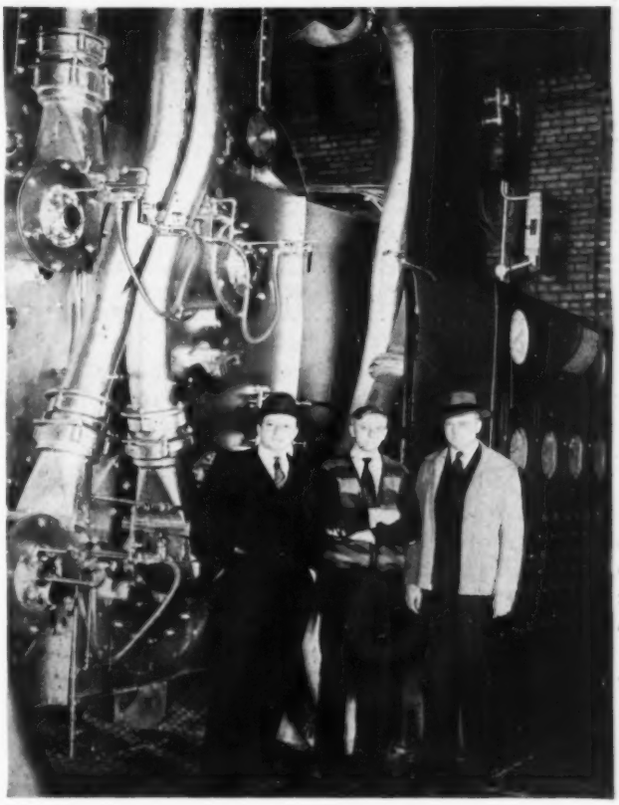
The Hagan combustion control functions through a master controller connected to the main steam header and conveniently coordinates the various combustion functions from the regulation of coal feed to the forced- and induced-draft fans. This control has not only contributed to a reduction in the coal bill but it proved most important during the war years when there was a shortage of trained operating personnel.

Feedwater Supply and Treatment

Raw water, which is low in hardness, is taken from the river and pumped through sand filters, then through a Permutit water softener. Coagulant and alkali are added ahead of the filters for flocculating and suspended matter. The softened water, which comprises about 50 per cent of the total, is pumped to a surge tank into which also enter condensate returns from the manufacturing plant. This supply then passes through oil removal filters and both alkali and coagulant are added. Next the feedwater enters a Cochrane deaerating heater to which is added sodium phosphate and caustic soda. Very close control of the water conditioning is maintained by the Cyrus Wm. Rice & Co., feedwater chemists, who receive weekly and monthly samples of the water and who also conduct annual surveys. A typical water analysis is shown in Table 2.

TABLE 2—TYPICAL WATER ANALYSIS

Analysis	River Water	Zeolite Treated Water
Temporary hardness, $CaCO_3$	18.8	0
Permanent hardness, $CaCO_3$	3.4	0
Phenolphthalein Alk, $CaCO_3$	0	...
Methyl orange Alk, $CaCO_3$	18.8	17.1
Total dissolved solids	35.3	44.7
Suspended matter	1.4	0.3
Calcium bicarbonate, $Ca(HCO_3)_2$	16.0	1.3
Magnesium bicarbonate, $Mg(HCO_3)_2$	2.4	1.7
Sodium bicarbonate, $NaHCO_3$	0	23.0
Calcium sulphate, $CaSO_4$	0	0
Magnesium sulphate, $MgSO_4$	4.2	0
Sodium sulphate, Na_2SO_4	0	10.0
Calcium chloride, $CaCl_2$	0	0
Magnesium chloride, $MgCl_2$	0.06	0
Sodium chloride, NaCl	8.4	6.8
Silica, SiO_2	3.2	1.4
Iron and alumina, $R2O_3$	0.5	0.5
PPhH	7.0	7.0
Permanganate consumed, $KMnO_4$	4.8	4.4
Total hardness	21.2	3.0



Boiler front and control board, with F. Stein, A. S. Oliver and P. Laurence in foreground

Performance of Unit

Since being placed in service initially in April 1942, excluding periods when the plant was tied up by strikes and interruptions in material supply, this VU-type steam generator has been in operation 1444 days during which it produced over 2,385,000,000 lb of steam.

With the plant load geared to war production it was impossible to take this unit off the line for internal inspection as frequently as would have been the case in normal times, or if the plant had contained sufficient steam generating capacity. Consequently our records show extended operating periods of 432, 357 and 346 operating days without opportunity for internal cleaning. Despite this, continued efficient steam production was obtained. Operating data sheets showed average ratings of 200 to 230 per cent with peaks of 318 per cent during which overall efficiencies of 83 to 86 per cent were maintained. Minor slag difficulties were overcome through additional lancing and will be further remedied by soot blowers.

As to the performance of the auxiliary equipment, there was no interruption due to the forced-draft fan and only slight difficulty was encountered with the magnetic drive on the induced-draft fan, where a tendency toward

over-heating was overcome by venting cool air around the drive.

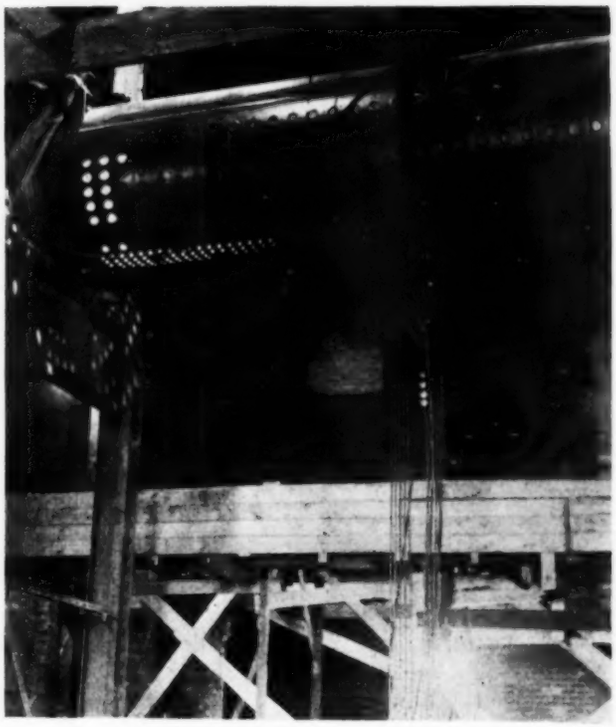
Data on the Raymond pulverizer operation from April 1, 1942, to March 31, 1946, inclusive, were as follows:

Tons of coal pulverized (2 mills)	95,987
Electricity to pulverize 95,987 tons	1,079,852 kwhr
Total power cost at 0.003 per kwhr	$3,239.55
Maintenance material cost	$762.00
Maintenance labor cost	$318.00
Total maintenance cost per ton of coal	$0.0112
Power cost per ton of coal	$0.033
Total cost per ton of coal (power and maintenance)	$0.0442

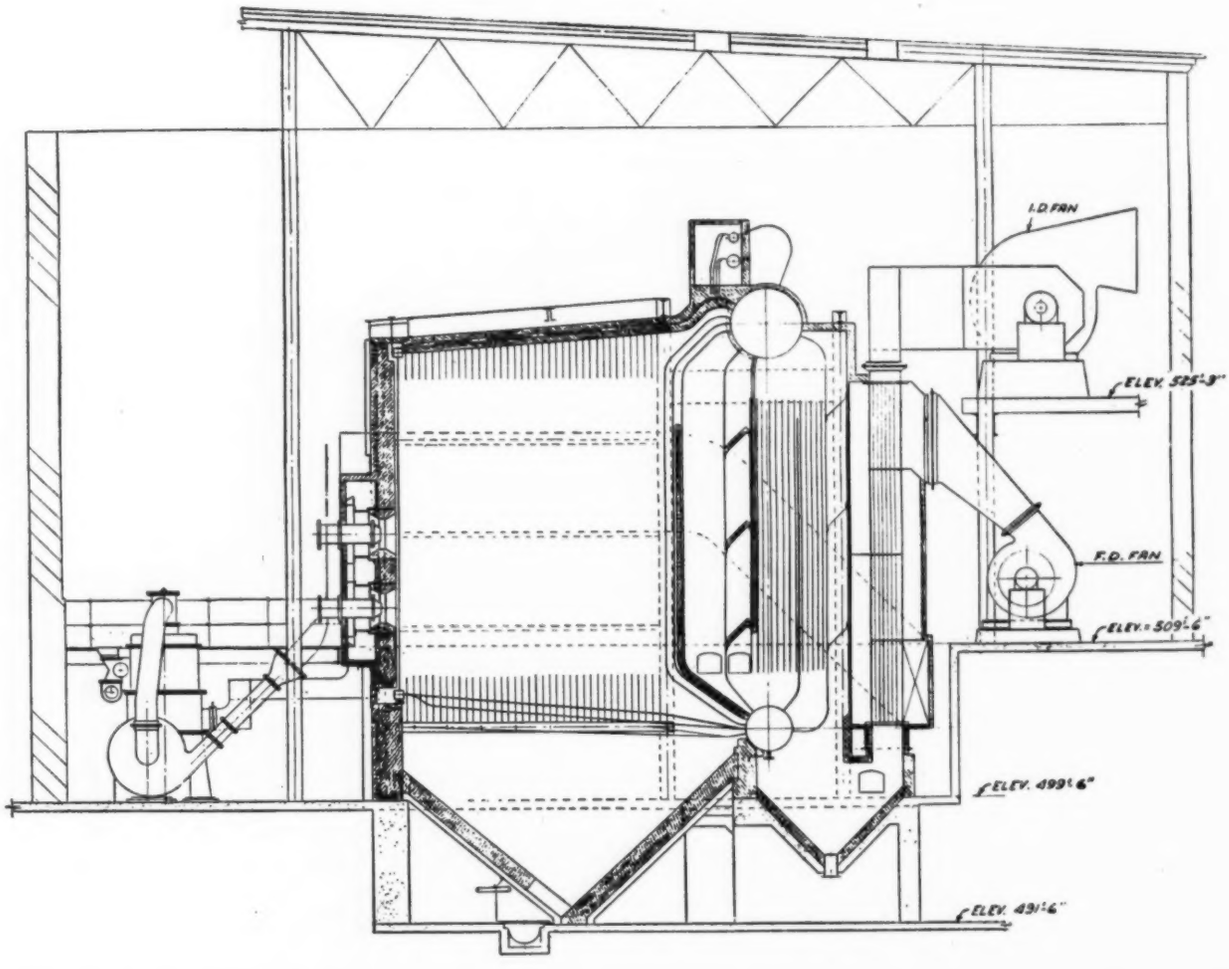
The combustion control requires routine cleaning of pilot valves, since these have a tendency to accumulate a gummy deposit, but during such cleaning manual control is readily accomplished.

An overall appreciation of results may be had when it is considered that the two 4000-kw turbines have been in continuous operation for from 2 to $3^1/_2$ yr without being dismantled and are continuing to carry full load, which attests to the high quality of steam production without carryover and subsequent deposits on turbine blading.

The pressing need for power and process steam continues and another C.E. VU-type steam generating unit similar in design but of 150,000 lb per hr rating was ordered and is now being installed.



Drum for new unit in position



Section through existing 90,000-lb. per hr unit

Quick Starting of High-Pressure Steam Turbine Units

By J. C. FALKNER,* R. S. WILLIAMS† and R. H. HARE††
Consolidated Edison Company of New York

This paper, which was presented at the recent A.S.M.E. Semi-Annual Meeting in Chicago, describes a new method of quick starting high-pressure steam turbine units at locations where, because of relatively light night loads, some of the high-pressure units must be shut down each night and started early in the morning. The method described reduces the thermal starting-up stresses in the turbines and boilers, reduces the starting fuel losses and the personnel required, and increases the available reserve factor as compared with the conventional methods of starting up.

FOR many years the turbines of the Consolidated Edison Company of New York have been started in the conventional manner as prescribed by the manufacturer, which calls for approximately 90–120 min to put the turbine on the line. As the load grew and the number of turbines increased, it became necessary, due to the load characteristics, to shut down approximately thirty-five turbines each night, some of which are topping units, and start them up again the next morning. At present there are six topping turbines and forty-four condensing turbines, with three additional topping turbines and four condensing turbines to be installed by 1951.

System Load and Capacity

The system load of the Company has almost doubled in the last 16 years, as the following figures indicate:

Year	Net Generator Output for the Year, Kwhr	Peak—Gross Generated per Hour, Kw
1930	4,983,512,182	1,282,000
1946	9,706,321,290	2,326,000

No new stations have been added to take care of this load increase, but it has been accomplished by modernizing the existing stations through the introduction of topping units exhausting into the low-pressure mains.

Fig. 1 shows typical hourly loads for a winter day in 1930 in comparison with 1946, and there has been added an estimated peak day for 1950 There is no marked morning peak; the load increases rapidly at a fairly uniform rate from 7 a.m. to 10 a.m., levels, with a noon drop of about 15 per cent and then climbs from 3 p.m. to a peak at 5 p.m. It then falls at a fairly rapid uniform rate to a low at 4 a.m.

Our system is tied in with the Niagara-Hudson Corporation for power interchange. During periods of high run-off we may be receiving hydro power up to 150,000 kw per hour which still further reduces our night load. When this situation arises the system load generation is as follows:

Station	Kw	Present Capacity, Kw
Hudson Ave.	80,000	770,000
Sherman Creek	50,000	221,000
Hell Gate	160,000	630,000
Waterside	160,000	438,000
Gold Street	Shut down	111,000
East River	Shut down	280,000
Long Island	Shut down	89,000
Port Morris	Shut down	60,000
All Stations	450,000	2,599,000

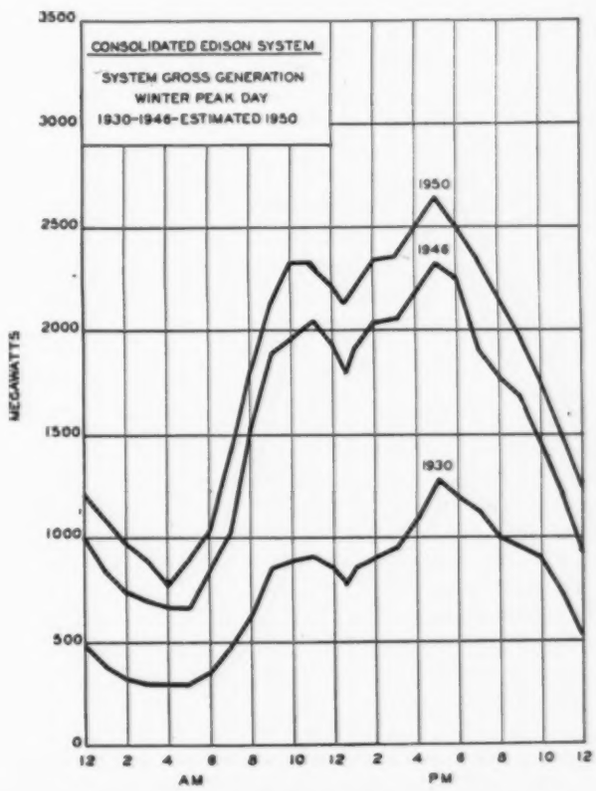
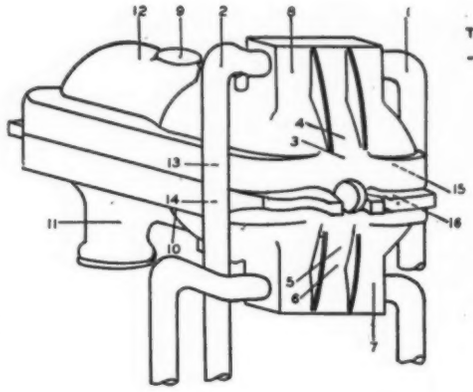


Fig. 1—System load characteristics

* Manager, Electric Production Department
† Superintendent, Waterside Station
‡ Assistant Engineer, Waterside Station



THERMOCOUPLE NUMBER	POINT OF INSTALLATION	TEMPERATURE CHANGE OF TURBINE METAL AFTER ROLLING START	
		QUICK	NORMAL
1.	STEAM INLET-RIGHT SIDE.	55	125
2.	STEAM INLET-LEFT SIDE.	55	125
3.	TOP CASING-HEAD END-AT GLAND.	95	80
4.	TOP CASING-HEAD END-ABOVE GLAND.	80	80
5.	BOTTOM CASING-HEAD END-UNDER GLAND.	25	35
6.	BOTTOM CASING-HEAD END-ABOVE VALVE CHEST.	10	35
7.	VALVE CHEST-BOTTOM CASING-HEAD END-RIGHT SIDE.	0	15
8.	VALVE CHEST-TOP CASING-HEAD END-LEFT SIDE.	45	125
9.	TOP CASING-OVER SEVENTH STAGE.	80	60
10.	BOTTOM CASING-UNDER SEVENTH STAGE.	30	20
11.	ON EXHAUST PIPE.	130	120
12.	TOP CASING-EXHAUST END.	130	140
13.	TOP FLANGE-LEFT SIDE.	45	50
14.	BOTTOM FLANGE-LEFT SIDE.	45	50
15.	TOP FLANGE-RIGHT SIDE.	45	50
16.	BOTTOM FLANGE-RIGHT SIDE.	45	50

Fig. 2—Diagram showing location of thermocouples and corresponding temperature changes of metal

The 80,000-kw load at the Hudson Avenue Station is the minimum load carried by two 160,000-kw turbines with most of the thirty-two stoker-fired boilers in a banked condition, ready to carry 770,000-kw load by 9:00 a.m.

The 50,000-kw load at the Sherman Creek Station is the minimum load on one high-pressure topping turbine, with one high-pressure boiler, plus the necessary low-pressure condensing turbines.

The 160,000-kw load at the Hell Gate Station is the minimum load on one high-pressure topping turbine with two high-pressure boilers, plus the necessary low-pressure condensing turbines to carry the minimum exhaust from the high-pressure turbine and 600,000 lb of steam per hour from the low-pressure boilers. This low-pressure boiler evaporation is necessary to supply makeup to the high-pressure boilers and to furnish generated load for regulation on the system.

The 160,000-kw load at the Waterside Station is the minimum load on four high-pressure topping turbines, with seven high-pressure boilers, plus the necessary low-pressure condensing turbines. Two topping turbines, plus the necessary low-pressure condensing turbines are sufficient to carry this load; therefore, one, or possibly two, may be shut down.

Principle of Quick-Start Method

The "quick starting" idea was discussed with the General Electric and Westinghouse turbine engineers approximately two years ago, and consists of simply admitting steam to the turbine at a temperature corresponding to that of the main parts of the turbine, such as valve chest, heavy flanged joints, top and bottom of casing, etc., after a shut-down period up to ten hours.

It is well appreciated that starting and stopping high-pressure, high-temperature boilers and turbines two hundred or more times per year introduces problems not heretofore encountered. With this in mind, investigations were made to see what could be accomplished in a way that would reduce the heat stresses in both turbine and boilers to a minimum and to reduce the starting cost, which in itself is a considerable item. As our greatest number of high-pressure units are at Waterside, the investigation was made at that location.

The present high-pressure installation at this station consists of four units, each made up of two boilers and one high-pressure turbine, the turbines exhausting into a common 200-psig header, which supplies steam to seven low-pressure condensing turbines and to two steam mains of the New York Steam Corporation. The capacities of the boilers and the turbines are as follows:

HIGH-PRESSURE BOILERS

Two Boilers per Unit

Unit No.	Manufacturer	Rating Each, Lb/Hr	Steam Press. Temp. Psig	F
4	Combustion	500,000	1200	900
5	Combustion	500,000	1200	900
6	Combustion	615,000	1250	925
7	B & W	615,000	1250	925

HIGH-PRESSURE TURBINES

One turbine per unit

Unit No.	Manufacturer	Rating, each, Kw
4	Westinghouse	53,000
5	General Electric	53,000
6	Westinghouse	65,000
7	General Electric	65,000

As a first step in the investigation, thermocouples were installed in the main leads to the turbine throttle, on the turbine steam chest and at different locations on the turbine cylinder and flanges on all four of the Waterside high-pressure turbines. The locations of these thermocouples on unit No. 7 are shown diagrammetically in Fig. 2.[1] Normal *operating* temperatures at these locations are.

Location	Deg F
1	925
2	925
3	830
4	840
5	850
6	860
7	920
8	920
9	765
10	765
11	525
12	520
13	745
14	745
15	745
16	745

[1] The complete paper contained similar diagrams for Units 4, 5, and 6 which are here omitted because of space restrictions.
[2] The complete paper contained similar curves for Unit No. 6.

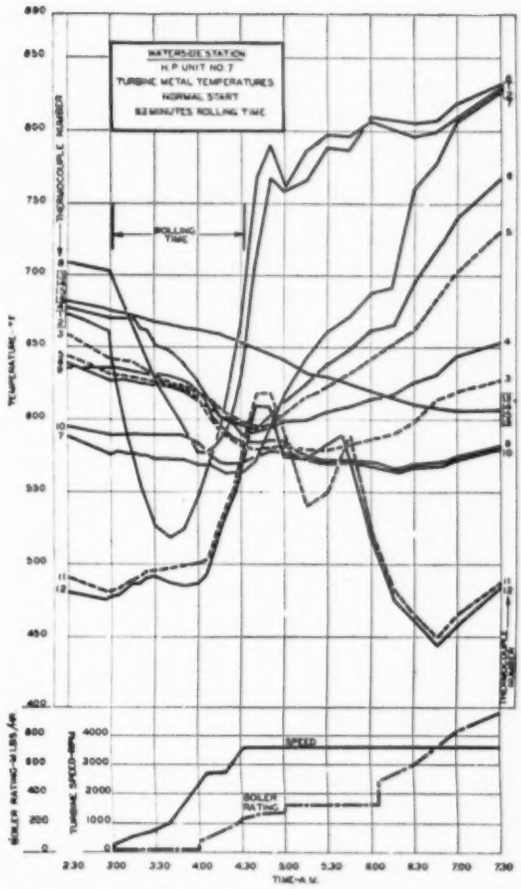


Fig. 3—Metal temperatures of Unit No. 7 with normal start

The temperatures found for normal *start-up* for Unit No. 7 are shown in Fig. 3[2] for each of the test locations, and on the bottom of these curves are given the turbine speed and the boiler output plotted at 30-min intervals.

A study of these data revealed that the superheater and line drains were normally left open, so that the boiler pressure was reduced to 200–400 psig at the beginning of the rolling period, and was then gradually increased to approximately 800 psig at the time the turbine was up to speed. It was noted that the steam chests with temperatures of 650–700 F at the start were actually cooled 50 to 120 deg F during the first hour of the rolling period due to the low initial steam temperature and the length of the rolling period. At the time the generator was synchronized, the steam chest temperatures had been brought back to approximately the same as at the beginning of the rolling period.

Following the idea of maintaining minimum temperature differences between the turbine and the entering steam, the quick start-up procedure was developed. It was determined that the boiler could be "bottled up" by closing the induced-draft fan vanes, boiler stop valves, superheater and line drains, so that after an outage of six or seven hours the boiler pressure was approximately 850 psig. It was also found that at low steam flows from the boiler, the steam temperature could be readily controlled by varying the excess air. Test start-up procedures were then formulated for the boilers and turbines in an attempt to hold heat in the boiler and to eliminate the cooling effect on the turbine by rolling it with steam at a temperature approximately the same as that of the metal temperature of the turbine casing.

Quick Start-up Procedure

Shut Down:

1. When the turbine is to be shut down, maintain normal drum pressure on both boilers, and take one off the line in a normal manner.
2. When rating is zero, on the boiler taken off, open the superheater drain until pressure falls to 1000 psig; then close the superheater drain, the fan vanes, the boiler stop or non-return valves.
3. Drop rating on second boiler, in normal manner to 300,000 lb per hr, maintaining normal drum pressure.
4. Boiler operator shall notify the High Board that boiler is at 300,000 lb per hr rating.
5. Both coal feeders are then tripped on this boiler.
6. High Board shall signal "Load Off" at 5000 kw, and 1000 psig boiler pressure.
7. Turbine throttle shall be tripped (turbine to be kept on turning gear).
8. "Bottle up" second boiler as prescribed in (2) above.
9. If during the outage period the drum pressure falls below 700 psig on either boiler, bring pressure back to 850 psig by intermittent coal firing.

Starting Up:

10. When the turbine is to be started the turbine room engineer shall note the temperature of the selected turbine casing thermocouple and give this temperature to the boiler control operator.
11. Boiler operator shall purge one boiler furnace, crack open the superheater drain, light ignition gas, open the superheater drain wide, and put one coal feeder in service.

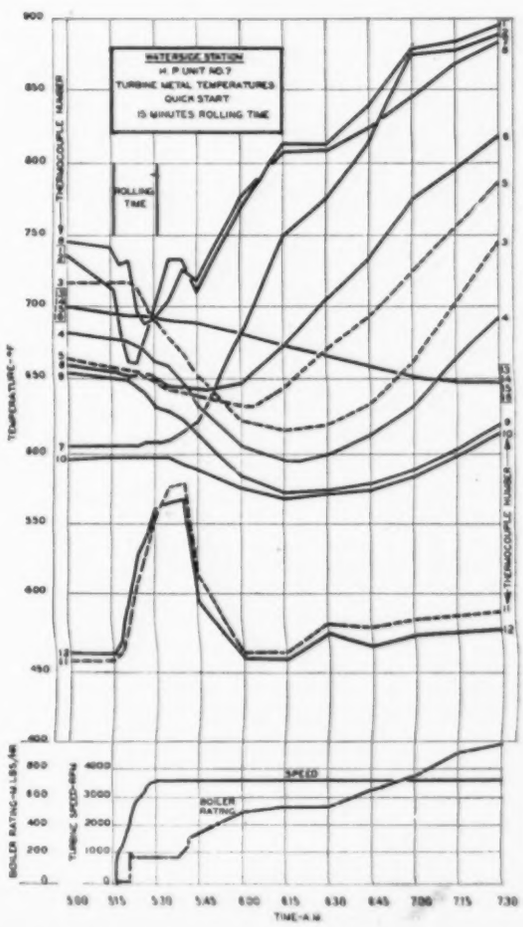
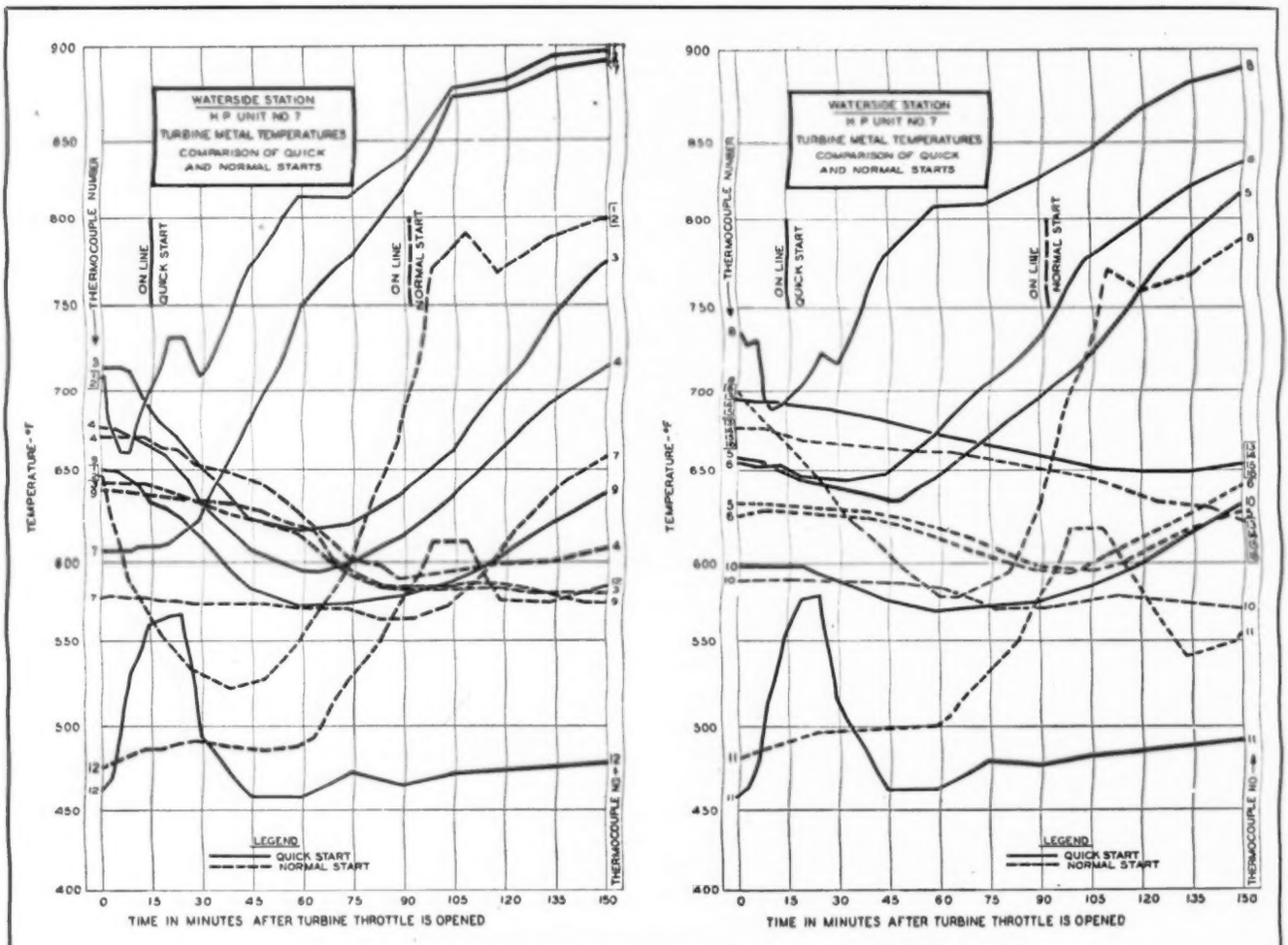


Fig. 4—Metal temperatures of Unit No. 7 with quick start



Figs. 5 and 6—Comparison of metal temperatures of Unit No. 7 with quick and normal starts

12. Boiler operator shall maintain steam temperature at the superheater outlet as near as possible to the turbine casing temperature, as given in (10). (This regulation is obtained by adjusting the excess air.)
13. The superheater bypass damper shall be kept open.
14. When the boiler pressure has been stabilized at 800 to 850 psig, open the turbine throttle and roll the turbine, increasing speed at a rate of approximately 300 rpm per minute.
15. Both coal feeders shall be placed in service within seven minutes after the turbine rolls.
16. Generator shall be synchronized within 15 min after start of the roll.
17. During the entire rolling period the turbine metal and inlet steam temperatures shall be checked at frequent intervals.
18. Both coal feeders shall be maintained at approximately minimum speed and superheater drain shall be closed.
19. During the rolling time, the second boiler shall be lighted off and its pressure brought up to within 200 psig of line pressure.
20. As soon as the turbine is on the line, the second boiler shall be put on the line with superheater drain and bypass damper wide open. The excess air shall be regulated in order to hold the steam temperature of the second boiler at the same temperature as the first.
21. Both boilers shall be at line pressure within 20 min.
22. Superheater bypass damper shall be regulated to increase steam inlet temperature at the rate of 100 deg F per hour.
23. The turbine shall be loaded in the normal manner.

A complete set of start-up data, using the quick start-up procedure was taken for each unit after a five- to seven-hour shut down. Fig. 4 shows the metal temperature changes during this method of starting for Unit No. 7. It may be noted that the cooling of the steam chest and heavy metal of the turbine casing was reduced considerably as compared with that of the normal start-up, and that the temperature stresses were not increased. For comparison between the conventional and the quick start-ups, see Figs. 5 and 6.

The 200-psig turbine exhaust temperature charts for both types of start-up are shown in Fig. 7 for Unit No. 7. Note the length of time the exhaust temperature remains high for the normal start-up as compared with the quick start-up.

Vibrations at various points on the turbine are better, or the same, during the quick start-up as with the normal. With the quick-start method the difficulty of bringing the unit through the critical speed period is completely eliminated.

The relative movement between the top casing and the stationary pedestal showed no change with one manufacturer's machine and a decided change on another. Turbines Nos. 5 and 7 have double casings so it is impossible to know the movement of the inner one, but with less chilling there should be less movement and less strains set up.

No increase in stator or field maintenance due to quick starts of the units is anticipated.

Conclusions (Based on 24 Quick Starts)

With the reduction of starting time for the high pressure turbines, the existing personnel will be sufficient to take care of all necessary starts. By not increasing the personnel, and with the reduction in starting costs, there will be an appreciable saving. In addition, this method will also be used at such times as either boilers or turbines must be taken off the line for minor maintenance. The quick start-up reduces the thermal stresses in the turbine and boiler; it reduces fuel costs for idle rolling, as well as additional personnel costs; and gives a better available reserve factor.

Quick starting may also be used on low-pressure turbines taking steam from a main steam header, fed from any number of boilers and with other turbines running from the header, as long as desuperheating water is in-

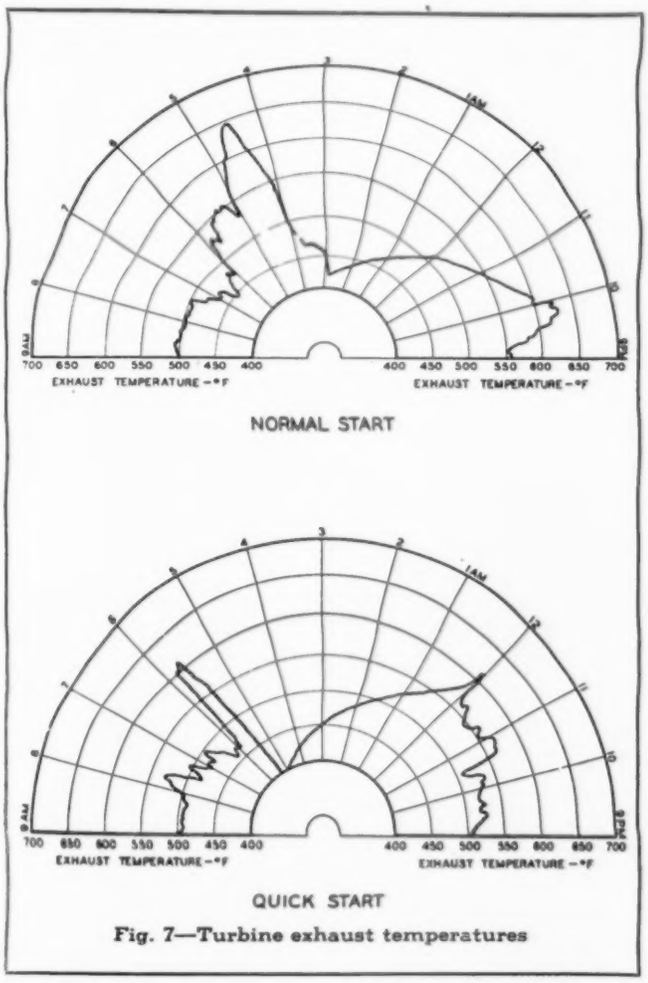


Fig. 7—Turbine exhaust temperatures

jected into the steam used for starting the turbine, and the temperature of the inlet steam is held equal to the temperature of the turbine inlet valve, heavy flanged parts, and turbine casing.

With the conventional start, high-temperature steam is used to start a unit that may be several hundred degrees cooler, with a resultant quick expansion toward the generator of the turbine spindle, which heats up more rapidly than the casing. This reduces the clearances between stationary and rotating parts and may cause serious damage.

Corrosion as Related to Acid Cleaning

WITH the widespread employment of acid cleaning of boilers to remove deposits from internal surfaces, questions have arisen from time to time as to whether this procedure may have been responsible for certain cases of corrosion. Taking cognizance of such reports, the Prime Movers Committee of the Edison Electric Institute, through its Subcommittee on Chemistry, sent a questionnaire to its member companies, to which 25 replied. The results are discussed in the report on "Boilers and Combustion, 1946" which has just been published.

Of the 25 companies replying, 17 employ acid cleaning and the majority opinion indicated that corrosion does not generally accompany acid cleaning. Of six stations reported as having encountered corrosion, two appeared to be doubtful cases. The nature and location of such corrosion was honeycomb attack on tube ends and handhole caps, corrosion of tube-roll bells and in highly stressed bend areas, as well as general etching of the surface affected.

High-Acid Temperatures and Concentrations Favor Corrosion

A study of the data showed that the group classified as having encountered corrosion had employed somewhat higher temperature of the acid than those who had no corrosion; that is, the average temperature for the former was 175 F and for the latter 155 F. The data indicated that as a precaution against corrosion, high acid temperature, high acid concentration and keeping the acid too long in the boiler should be avoided. The desirable limits appeared to be 155 F, 5 per cent acid concentration and $5^1/_2$ hr. Local areas of high acid temperature resulting from too high metal temperature should be avoided.

The Committee failed to discover from the questionnaires any connection between corrosion and the inhibitors employed, and the opinion was expressed that inhibitors tend to be less effective at high temperatures and at higher acid concentrations; also, in some cases the inhibitor may materially reduce the rate at which deposits are removed and therefore increase the time of contact required.

Boiler deposits reported consisted generally of black iron oxide and copper with occasional small amounts of calcium phosphate and silica deposits, but there did not appear to be any relation between the nature of the deposits and the corrosion.

The usual practice after acid cleaning was to dump the acid and immediately fill the boiler with water, then to flush with an alkaline solution. For this purpose soda ash was generally used, although in two cases sodium hydroxide was employed and one used sodium metasilicate. One boiler was treated with a mixture of sodium hydroxide, sodium silicate and tri-sodium phosphate, the belief being that the silicate sets up a resistant coating on the metal. The alternate method of adding water to the boiler while the acid drains is not favored because it tends to precipitate dissolved material as the acid solution becomes diluted.

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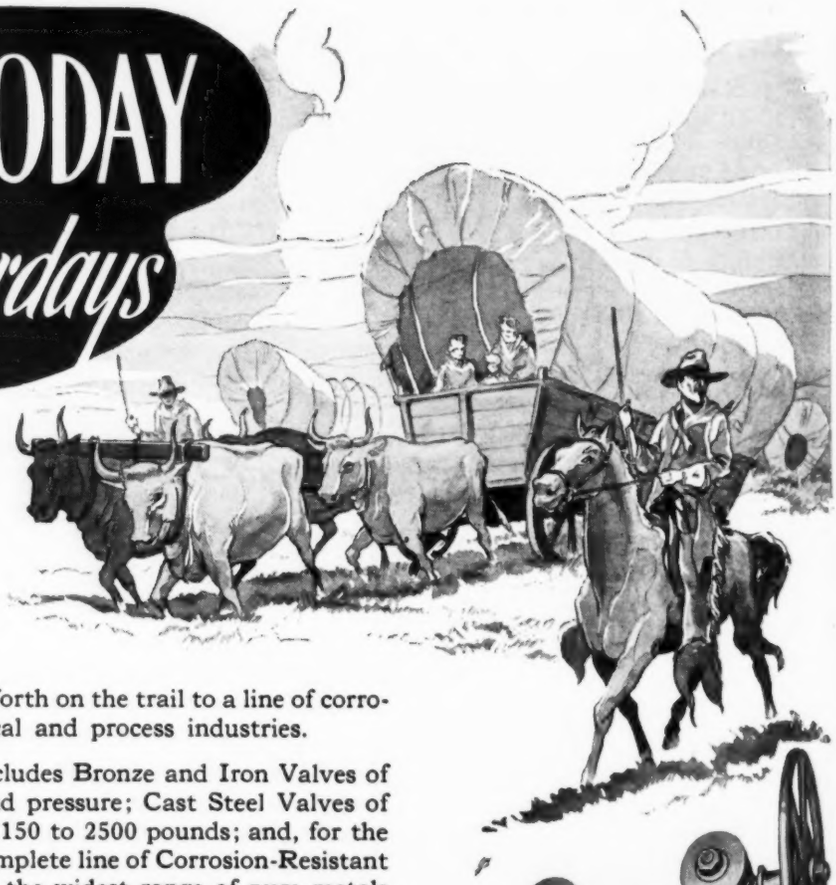

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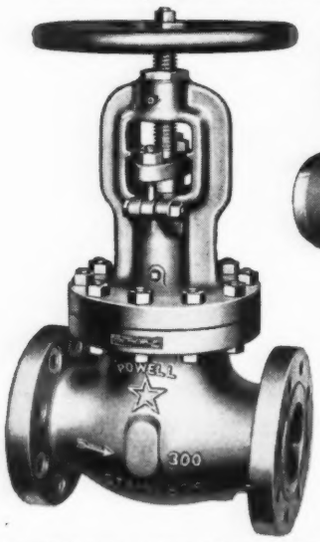

Fig. 3031 S. S.—Class 300-pound Stainless Steel Globe Valve, made to ASA dimensions and especially adapted for high pressure, high temperature boiler feed water treatment solutions. Has flanged ends, bolted flanged bonnet and outside screw rising stem. Also available with socket welding or butt welding ends.

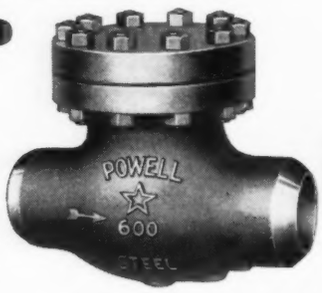

Fig. 6065 W. E.—Class 600-pound Cast Steel Horizontal Lift Check Valve with welding ends and bolted flanged cap.

Fig. 1323—Class 1500-pound, 8", Cast Steel Gate Valve with welding ends, welded bonnet and special by-pass. Top mounted electric motor operator provides quick, positive opening and closing by remote control.

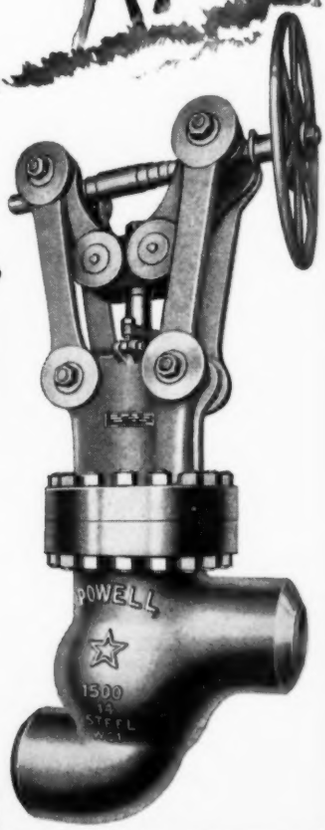

Fig. 1393—Class 1500-pound, 14", Cast Steel Non-Return Angle Valve with welding ends and bolted flanged bonnet. Toggle operated for easy opening and closing of valve.

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POWELL VALVES

Work of Fuel Research Station in Study of Boiler Deposits

In the March issue was published a digest of an interim report of the British Boiler Availability Committee on "External Deposits and Corrosion in Boiler Plants." The present notes are from a paper by Dr. H. E. Crossley, dealing with work on boiler deposits as carried on by the Fuel Research Station of the Department of Scientific and Industrial Research which has been collaborating with the Boiler Availability Committee. The investigation was directed mainly toward the types of deposit due to various constituents of coal.

SOME 700 samples of deposits from British power station boilers and 500 samples of coal were collected and examined at the Fuel Research Station.

The high-temperature deposits, in the form of "bird-nesting" on the tubes nearest the combustion chamber and as hard deposits on the superheater tubes, appear to be of three main types, which can be classified as re-fused ash, alkali-matrix and phosphatic. Most of the fly ash entering the boiler passes is in the form of spherical particles (See Fig. 1), highly colored in the case of stoker firing, but black and white with pulverized coal firing. These spheres are often solid when they settle on or pass the first tubes, but if the temperature is sufficiently high the spheres may be partly molten at this point, or a rise in temperature may melt them after deposition. The result is fusion into a clinkerlike mass. Such re-fused ash although common on the front steam-generating tubes, occurs less frequently on superheaters. While such formations are encouraged if the fly ash has a relatively low melting point, the main cause of the trouble is high temperature which is usually associated with the boiler design and method of operation.

The alkali-matrix type of deposit (Fig. 2) appears under the microscope as a whitish mass in which fly-ash spheres are embedded. When this is washed with water the whitish mass is mostly dissolved, leaving the fly-ash spheres which are not fused together.

The phosphatic type of deposit is relatively uncommon. When it does occur there is usually an outer hard shell which has a characteristic appearance when seen through the microscope, as in Fig. 3. Inside the shell is a soft cone of fly ash which, if treated with phosphoric acid, gives a substance resembling the shell as shown in the photomicrograph of Fig. 4.

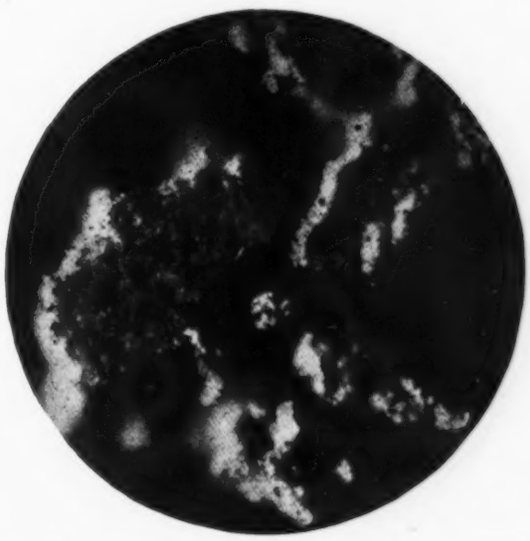

Fig. 2—Photomicrograph of alkali-matrix deposit

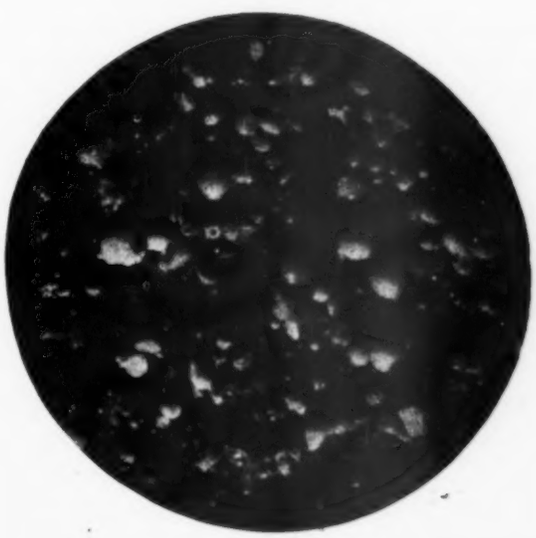

Fig. 1—Photomicrograph of fly-ash spheres

Chemical Compositions

The chemical compositions of the three types of deposit show important differences, as revealed in Tables 1 and 2. The re-fusion type contains alkali oxides, sulphur trioxide and phosphorous peritoxide, similar to those found in coal ashes. The alkali-matrix type contains relatively large amounts of alkali oxides and sulphates, and the phosphate type a relatively large amount of phosphate, compared with coal ashes. The white substance which acts as the bonding agent in alkali-matrix deposits is rich in the sulphates or bisulphates of the alkali metals, sodium and potassium. The alkalis occur in coal in two forms — as relatively non-volatile constituents of the

TABLE 1—EXAMPLES OF THE COMPOSITION OF TYPES OF "BIRD-NESTING"

Constituent	Re-fusion Type: Whole Deposit, Blackish	Alkali-Matrix Type: White Inner Layer	Alkali-Matrix Type: Brown Outer Layer
SiO_2	30.7	9.2	21.6
Fe_2O_3	21.2	21.1	25.0
Al_2O_3	27.8	10.0	18.1
$(NaK)_2O$	3.6	14.7	9.5
P_2O_5	0.3	0.2	0.6
SO_3	2.9	29.8	20.6

shaly matter, and as chlorides which are easily volatilized. The chlorine content of coal has therefore been taken as a measure of the volatile alkalis present. The phosphates in deposits are derived from phosphorus compounds set free during the combustion of the coal.

Economizer and Air-Heater Deposits

It has already been shown that hard economizer deposits are of two main types, which may be called "sulphatic" and "phosphatic." The former is readily disintegrated by soaking in water, but the latter is not, because the phosphates are mainly those of aluminum and iron.

The most troublesome air-heater deposits are sticky and usually contain appreciable amounts of sulphuric

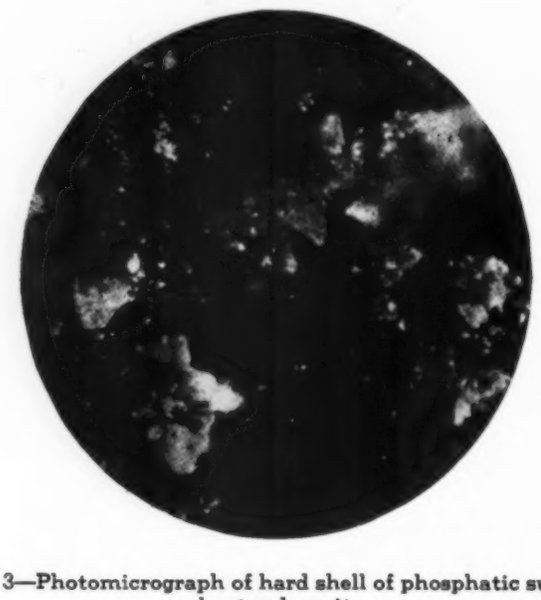

Fig. 3—Photomicrograph of hard shell of phosphatic superheater deposit

acid. The acid accumulates by condensation and the amount is affected mainly by temperature of the metal surfaces.

It is apparent, therefore, that the constituents of coal most concerned with troublesome deposits are alkalis (indicated by the chlorine content), sulphur and phosphorus. The results of twenty years work by the Coal Survey Laboratories of the Fuel Research Station include

TABLE 2—EXAMPLES OF THE COMPOSITION OF TYPES OF SUPERHEATER DEPOSITS

Constituent	Phosphatic Type: White Inner Layer	Phosphatic Type: Brown Friable Core	Phosphatic Type: Brown Outer Layer	Alkali-Matrix Type: Hard White Inner Layer	Alkali-Matrix Type: Brown Outer Layer	Alkali-Matrix Type: Hard Layer	Re-fusion Type: White Inner Layer	Re-fusion Type: Blackish Hard Outer Layer
SiO_2	49.9	43.0	42.8	10.0	18.6	17.3	35.5	
Fe_2O_3	7.8	6.2	5.7	14.5	15.6	28.3	23.4	
Al_2O_3	6.2	22.4	18.1	2.0	17.5	11.1	21.7	
$(NaK)_2O$	4.4	0.5	0.5	24.9	12.8	8.6	3.5	
P_2O_5	10.6	3.5	8.2	2.6	2.5	0.2	0.3	
SO_3	6.5	1.8	1.8	42.5	27.3	30.9	6.0	

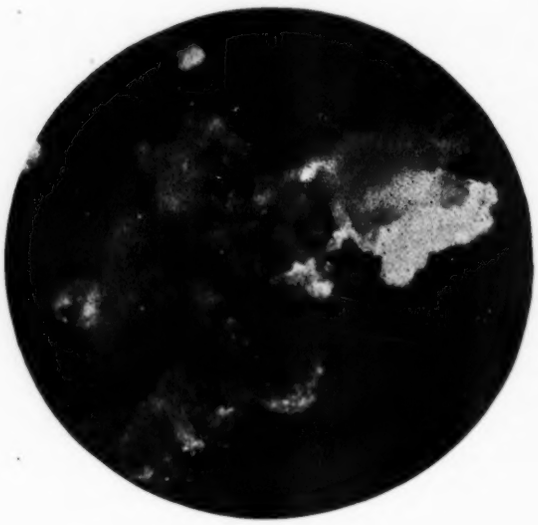

Fig. 4—Photomicrograph of fly ash treated with phosphoric acid

sufficient information on the chlorine, sulphur and phosphorus contents of British coals to enable classification of the amounts of these constituents into high, medium and low groups as indicated in Table 3.

Investigation has shown that phosphorus compounds are not volatilized during the combustion of pulverized coal, hence no appreciable phosphatic deposits are found even when burning coal of relatively high phosphorus content. There is a relatively slow volatilization of phosphorus from traveling grates when burning high-phos-

TABLE 3—CLASSIFICATION OF THE AMOUNTS OF CHLORINE SULPHUR AND PHOSPHORUS IN BRITISH COALS

Constituent	Classification limits, per cent of coal: High	Medium	Low
Chlorine	Over 0.3	0.15 to 0.3	Less than 0.15
Sulphur	Over 1.8	1.3 to 1.8	Less than 1.3
Phosphorus	Over 0.03	0.01 to 0.03	Less than 0.01

phorus coals and a correspondingly slow development of phosphatic deposits. In deep fuel beds, such as employed with retort stokers, however, phosphatic deposits can form rapidly when the fuel-bed temperatures are high. Where only a little phosphoric acid is present in the flue gases, the greatest amount of condensation is usually either near the boiler outlet, or in the economizer section. No case has yet been found where coals of low or medium phosphorus content have been associated with phosphatic deposits.

Effects of Chlorine

Correlation was then sought between the chlorine content of coals burned, and trouble from high-temperature deposits of the alkali-matrix type, and between the sulphur content of coals and air-heater deposits and corrosion.

Of the power stations burning coals of high- and medium-chlorine content, twenty-eight had stoker-fired boilers and eight burned pulverized coal. All the stoker-fired stations reported deposits on the front bank of boiler tubes and superheater as the principal cause of outage,

with the average boiler run between 980 and 1180 hr. On the other hand, none of the eight pulverized-coal-fired plants reported deposits other than re-fused ash.

Eleven plants burned coals of a mixture of high-, medium- and low-chlorine types, all stoker-fired. Ten of these had shutdowns due to deposits on the front boiler bank and superheater; and the eleventh plant, which also used pulverized coal, reported no trouble of this character.

At nineteen power stations the coals were of medium- and low-chlorine content. Eighteen of these employed mechanical stokers. Only five of the eighteen reported outages from high-temperature deposits, with average boiler runs of 2700 to 3600 hr.

Seventeen stations reported burning low-chlorine coal. Fifteen of these had stokers and two employed pulverized fuel. None of these stations, however, experienced trouble from deposits.

Trouble Reported from Sulphur

In the correlation of sulphur content of coal with air-heater deposits and corrosion, at ten stations burning medium- to high-sulphur coal, nine had mechanical stokers and reported trouble, the boiler runs without shutdown being from 1380 to 1610 hr. Of ten other stoker-fired plants burning low-, medium- and high-sulphur coal, four reported acute trouble and the remaining six only minor trouble with air-heater deposits. On the other hand, eight stoker-fired and four pulverized-coal-fired plants burning low-sulphur coals reported no trouble.

It was therefore apparent that, from the standpoint of chlorine and sulphur contents of the coals, air heaters of boilers fired with pulverized coal were affected much less than those that were stoker fired.

Pulverizer Capacity

Two factors generally recognized as affecting pulverizer capacity are grindability of the coal and its moisture content. While the former is a matter of fuel availability, the effect of the latter can be controlled through equipment design. The influence of high moisture on mill capacity can be rendered small if air at sufficiently high temperature is made available for mill drying. It follows that in selecting equipment to handle coals which are likely to have a wide range in grindability and moisture content, it becomes necessary to choose pulverizers sufficiently large to take care of coal of the lowest grindability economically available to the plant, and also to so apportion the heat-recovery section of the steam-generating unit so as to provide air at a temperature that will dry the maximum moisture encountered.

Of course, when mills are selected on this basis they are likely to be oversize for normal operating conditions; and the range in steaming capacity with all mills operating will be reduced, because of the higher air-coal ratio at partial load. Therefore, it is desirable when selecting a pulverizer to specify as closely as possible the expected grindability range.

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1. A Cochrane Clarifier (Rapid Reactor) of 32,500 GPH capacity, the sedimentation tank of which appears above. The chemical feeds shown below (center) comprise coagulant and alkali tanks with proportioners and feed pumps. The proportioners are electrically controlled by an indicating, recording and integrating electric flow meter.

2. The Cochrane Vertical Pressure Filters are also shown below (right) and in the foreground an alkali tank with a stirrer for the addition of alkali to control the pH value after filtering.

3. A 3-unit Cochrane Carbite (Carbonaceous Zeolite) Softener. Maximum total rate of 543 GPM.

4. A Cochrane (Tray type) Deaerator of 320,000 lbs/hr consisting of 70,000 to 270,000 lbs. of condensate at 100°F. from surface condensers. The make-up comes from the Cochrane Zeolite Softener at 50°F. Water of zero oxygen is delivered to two boilers. This installation illustrates the versatility of Cochrane equipment and attests to the wealth of experience that makes possible this versatility.

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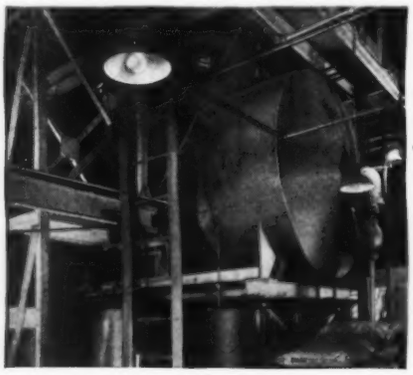
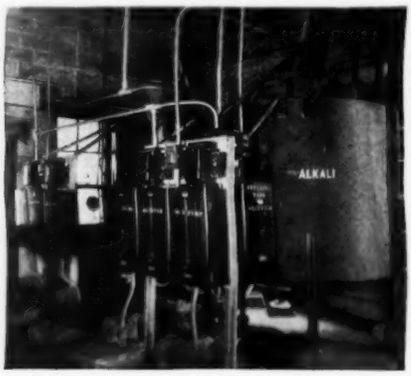


Cochrane Cylindrical Rolled Plate Deaerator with Storage Tank.



Cochrane Chemical Feed showing coagulant and alkali tanks with proportioners and feed pumps.

Cochrane Vertical Pressure Filters with an Alkali Tank in the foreground with a stirrer for the addition of alkali to control the pH value after filtering.

Some Notes on Boiler Practice in Germany

By Dr. F. O. A. MUNZINGER
Consulting Engineer, Berlin

For many years Dr. Munzinger was regarded as an outstanding authority on German power plant practice and, through his numerous books and published papers, prior to World War II, was well known to many American engineers. In this brief review of German practice he touches upon prevailing steam conditions, sizes of units and features of boiler design adapted to burning the lower grade high-ash coals. In a subsequent article, or articles, we expect him to discuss certain specific problems and how they were met.

BOILER construction and design have been greatly improved during the last twenty years. Steam pressures from 1100 to 2200 psi are now widely employed in German electrical and industrial power plants of any importance. The number of boilers in operation or under construction having a pressure of 1100 psi or more and their combined outputs at the end of 1932, 1938 and 1944 were as follows:

Year	Boilers	Combined Output, lb per hr
1932	8	800,000 (100,000 lb average)
1938	202	32,000,000 (158,000 lb average)
1944	448	78,000,000 (174,000 lb average)

Of 140 high-pressure boilers having individual ratings of 200,000 lb per hr and over, approximately two-thirds are working with natural circulation and one-third with forced circulation. Among the latter the Benson once-through type predominates. Only about 35 per cent of the total high-pressure boiler capacity (1100 psi and over) is installed in public utility plants. The reason for the larger proportion of high-pressure capacity having been installed in industrial power plants is that high steam pressure is far more advantageous in connection with the high back pressure of industrial power plants than in electric generating stations using a very high vacuum. The tendency to very high pressures is obviously demonstrated by the fact that of the total capacity of high-pressure boilers 34.2 per cent is in the 1100- to 1300-psi range, 24.5 per cent in the 1400 to 1700-psi range and 42.3 per cent 1750 psi and over. The highest pressure used is 2200 psi in 156,000-lb-per-hr natural-circulation boilers operating in a coal-mine power plant. Eighty-nine per cent of all German high-pressure boilers are fired by pulverized coal, 60 per cent using bituminous coal (Steinkohle) and 40 per cent brown coal, of about 4000 Btu per lb calorific value, and coke from brown coal low-temperature carbonization (Schwelkoks).

The largest of the German boilers is rated at approximately 400,000 lb per hr, whereas the average central station unit is around 250,000 lb per hr and the average for the larger industrial plants, such as chemical works, was around 150,000 lb per hr. Plants for the hydrogenation of brown coal by the Bergius process prefer relatively small boilers because the sudden outage of a large boiler with the consequent loss in capacity might seriously disturb the very sensitive process.

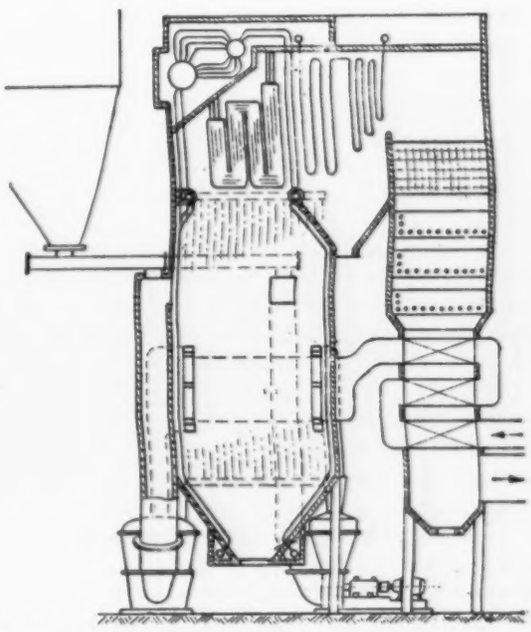


Fig. 1—Late boiler design embodying the so-called "channel" type superheater

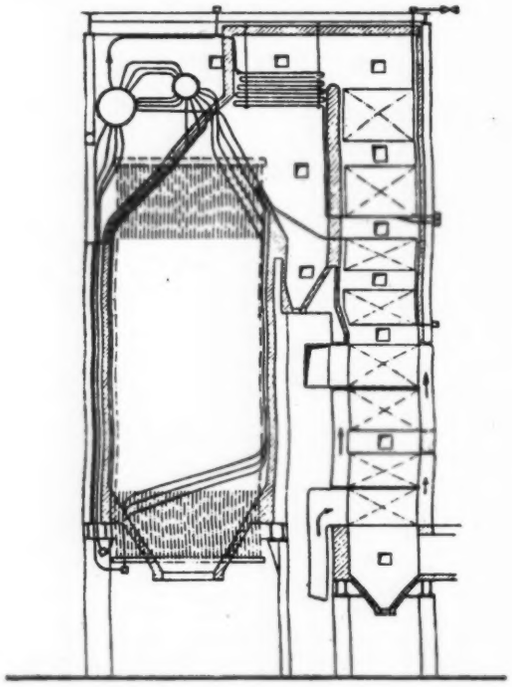


Fig. 2—Note separation drum and risers

Although Benson boilers are now working satisfactorily and with high efficiency, their share in the total number of high-pressure units going into service decreased from 12.1 per cent in 1939 to only 1.1 per cent in 1941. However, it is beyond the scope of this paper to deal with the rather complicated causes of this situation.

About 15 per cent of the high-pressure plants are employing steam temperatures from 885 to 910 F, about 70 per cent 930 F and 15 per cent 950 to 1000 F. It is the author's opinion that the future will see electric utility plants employing pressures of around 2300 psi with live and reheated steam temperatures of around 1100 F. Otherwise steam power will not long be able to compete successfully with gas turbines, especially with the aerodynamic gas turbine. Such turbines with an output of only 2000 kw have attained almost the same efficiency as the most modern steam power plants with 30,000 to 50,000 kw turbines.

Progress in German boiler construction has been due principally to three factors, namely:

1. Improvements in the manufacture of steels for high temperatures and improvements in the fabrication of large boiler drums.

2. Achievements in the investigation of circulation of boiler water and the uniform distribution of feedwater in the economizer; also the avoidance of hard deposits on the boiler, superheater and economizer tubes due to formation of sulphides of Si, Ca, Fe, etc., in the furnace.

3. Some new boiler designs embody the so-called "channel superheater" (Fig. 1), a separation drum (Fig. 2) and a clever arrangement of the risers with regard to the upper boiler drum and of the connections between this drum and the superheater. By the two latter means even with chemically treated feedwater and high steam pressures very clean steam can be produced.

The channel superheater, invented by the Kohlenscheidungs-Gesellschaft of Berlin, is of the radiant type and consists of tangent superheater tubes arranged in vertical planes spaced 2 to 3 ft apart. Thus the tubes present a relatively smooth surface to which molten ash particles cannot cling and the wide spacing prevents the bridging over of ash and slag.

With the Roeckner milling process steel ingots up to 70 tons can be rolled and seamless drums can be produced at moderate price, with a length up to approximately 60 ft, an outside diameter of 70 in. and a wall thickness of 6 in. The riveting of boiler drums has totally disappeared, practically all boiler drums being electrically welded, rolled or forged.

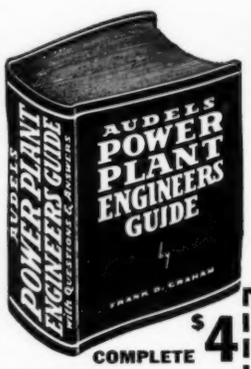
By the classification of all boiler steels in three groups, which must be carefully observed by all steel mills, the number of faulty tubes has been greatly reduced. According to the highest class, III, covering pressures of 1100 psi and above, the outer layers of the steel ingots have to be removed before they are milled and several tests and examinations of the tubes have to be executed before the tubes reach the boiler manufacturer.

The boiler and superheater tubes are almost without exception rolled into the drums and heaters. In the economizers all gaskets are carefully avoided because water of high pressure and high temperature rapidly deteriorates most gaskets.

The late Professor Foettinger and other German engineers have done much constructive work in formulating conditions for uniform distribution of feedwater in the economizer and of steam in the superheater tubes arranged in parallel; also by elucidating the causes of some cases of unstable water flow in boiler tubes under forced circulation. The latter work has been of great benefit to Benson boilers by putting an end to the burning of tubes, the causes of which could not be properly explained in former years.

In the design shown in Fig. 2 a steam-separating drum, having its own water level, is placed 3 to 5 ft above the upper boiler drum, with which it is connected by water and steam tubes. The boiler risers are connected with the separating drum and the downcomers and the superheater tubes with the upper boiler drum in a specific manner. Very pure steam is reported to be produced by this arrangement without plates or other drum internals.

With this arrangement even brown coals containing troublesome ash can be burned successfully. In this connection the necessity of burning very big quantities of low-temperature coke from brown coal with very agressive ash—at first causing endless trouble—has proved to be one of the most effective instigators of improvements in modern German boiler design.



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Thermodynamics of Steam and Gas Turbines Compared

The following abstract is from a paper by A. Meldahl, delivered before a large group of visiting engineers at the works of Brown Boveri & Co., Baden, Switzerland, and subsequently published in a special issue of The Brown Boveri Review. Entropy diagrams for both cycles are compared and the conclusions confirm the opinion that for large power stations the steam turbine will continue to be the more economical prime mover, whereas for smaller capacities the gas turbine in many cases offers attractive possibilities.

THE temperature-entropy diagram, Fig. 1, represents a simple steam process in which area 1 is the heat rejected to the condenser, area 2 the mechanical output, and 1 plus 2 the total heat supplied. While the efficiency seems fairly high, it is far from ideal; in fact, a Carnot cycle between the same temperature limits would give a rectangular diagram corresponding to a considerably higher efficiency.

Fig. 2 shows how the steam process may approach this ideal. The sum of areas 1, 2, 3, 4 and 5 represents the heat supplied, but part of this heat, 1 plus 4, is taken not from an external source but from the cycle itself, since steam corresponding to area 3 is extracted and used for heating the feedwater instead of going to the condenser. Consequently, area 3 equals areas 1 plus 4. Therefore, only the heat represented by 2 plus 3 plus 5 is supplied from the outside only and 1 plus 2 is ultimately lost to the condenser. The mechanical output is represented by 4 plus 5.

Thus with area 3 cancelling 1 plus 4, the simplified diagram, Fig. 3, may be considered in which areas 1 plus 2 represent the heat supplied from without; 1 being that lost to the condenser and 2 the theoretical output. Feedwater heating with bled steam will make the cycle approach the ideal Carnot.

A further improvement is possible if the steam is reheated, as shown in Fig. 4, but even with this, the cycle is far from the ideal.

Fig. 5 shows the temperature-entropy diagram of a single-stage gas turbine, the efficiency of which is not very high, since the output 2 is small compared with the total heat supplied, 1 plus 2.

A two-stage gas-turbine cycle is represented by Fig. 6 and shows considerable improvement over Fig. 5, both diagrams being drawn for the same amount of air. Fig. 6 further shows that a two-stage turbine plant delivers about twice the output for the same air quantity, from which it follows that for the same output the turbines and compressors will be smaller. On the other hand, the two-stage installation has the drawback that part of the lost heat area 1′, cannot escape directly to the atmosphere, but needs a special cooler.

As in the case of a steam turbine, part of the heat loss can also be recuperated with a gas turbine. This is shown in Fig. 7 where the total heat input is the sum of areas 1, 2, 3, 4 and 5, and the heat loss is 1 plus 2 plus 3. However, part of 3 is passed through a recuperator and is used for preheating the compressed air. The corresponding heat is represented by 1 plus

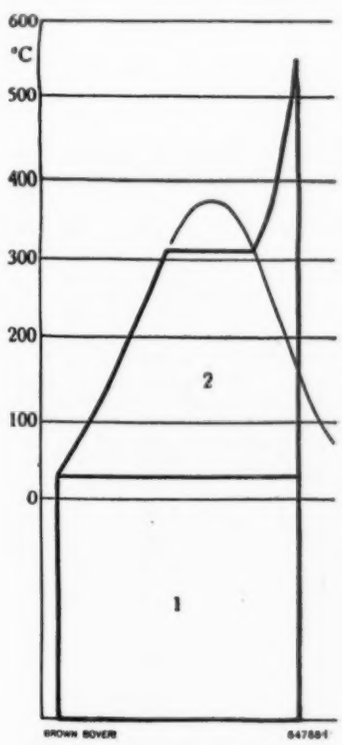

Fig. 1—Simple high-pressure steam cycle

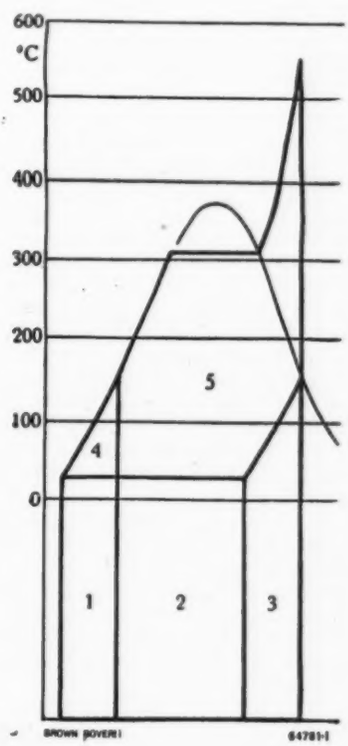

Fig. 2—High-pressure steam cycle with extraction for feedwater heating

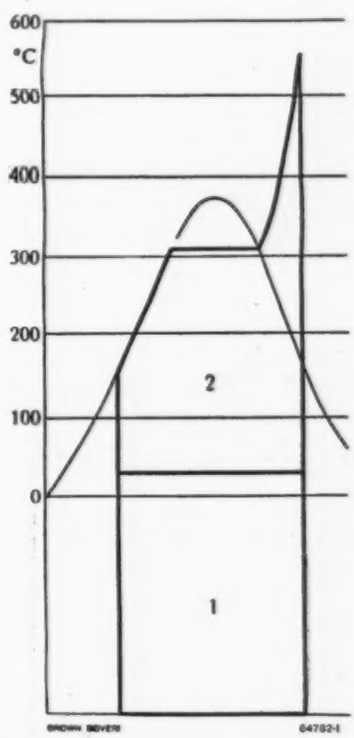

Fig. 3—Simplified diagram of high-pressure steam cycle with extraction for feedwater heating

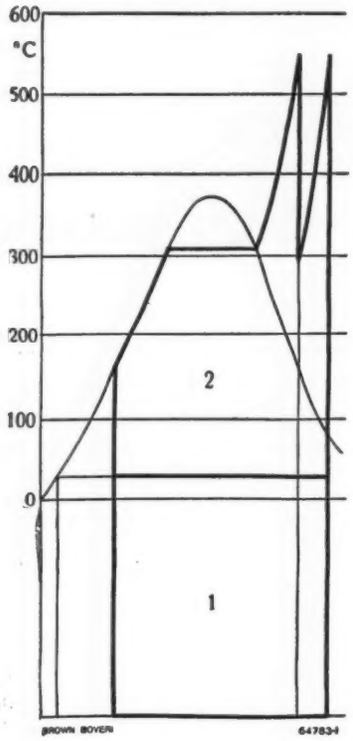

Fig. 4—Steam cycle with reheating

4. Consequently, only the heat shown by 2, 3 and 5 has to be supplied from without and the heat loss amounts only to 1 plus 2, with the output remaining 4 plus 5.

The areas 3 and 1 plus 4 again mutually cancel, thus giving the simplified diagram shown in Fig. 8. In this 1 plus 3 is the heat supplied, 1 plus 2 is that lost and 3 minus 2 is the mechanical output. Area 2 represents the loss from the temperature drop in the recuperator.

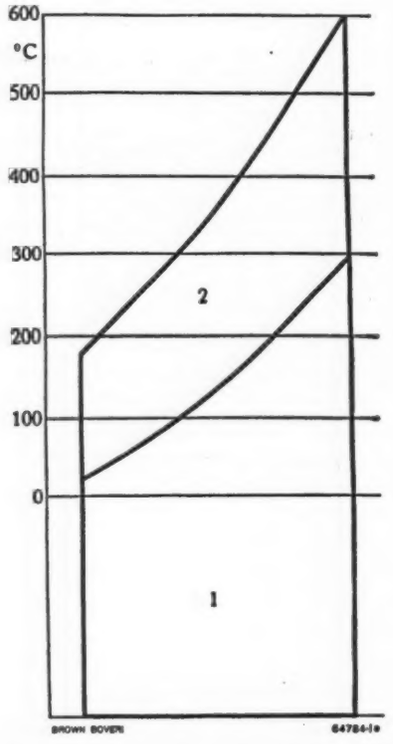

Fig. 5—Single-stage gas turbine cycle

Comparison of the steam- and gas-turbine diagrams shows the theoretical efficiency of the gas turbine to be superior, but from this it cannot be inferred that the gas turbine is really always better than the steam turbine, since the inevitable power plant operating losses are greater for the gas turbine. This is made clear in Figs. 9 and 10.

Fig. 9 is a diagram of a simple steam cycle, but unlike Fig. 1, the thermodynamic efficiency of the turbine is supposed to be 0.85 instead of unity. The heat supplied is 1 plus 3, that lost 1 plus 2 (the area 2 being the turbine loss) and the output 3 minus 2.

Fig. 10 shows the influence of losses on the gas turbine process. The heat supplied is 2 plus 4, and that lost is 1 plus 2 plus 3. It follows that the net output is 4 minus 1 minus 3, the area 1 being the compressor losses and 3 the turbine losses. Although the efficiencies of the turbine and the compressor are the same, the influence of the losses on plant efficiency is much more serious in the case of the gas turbine.

Conclusions

The efficiency of the gas turbine may be increased by employing a large heat-exchanger, but whether this may be worth while is an economic question. On the other hand, technical possibilities are rather limited where improvement of steam plant efficiency by means of feedwater heating is concerned.

A gas turbine gains much more from increase in inlet temperature than the steam turbine, and further increases in such temperature will be to its advantage.

Steam turbines cannot effectively utilize lower cooling water temperatures as the low-pressure blading cannot handle the enormous steam volumes. The gas turbine is not subject to such limitation.

The influence of low air temperature is particularly interesting. Cycle efficiency increases and compression work decreases in proportion to the absolute temperature. This compression input is, however, about three times the net output, and as the net output is the difference between turbine output and compressor input, the proportion of increase of net output is considerable. Furthermore, since an axial compressor works at approximately constant volume, the air delivery rises with lowering temperature. A decrease of 15 to 20 deg C in inlet temperature results in an increase of net output of about 25 per cent with an increase in efficiency of about 5 per cent. Consequently gas turbines are especially adaptable to winter peak load service.

As previously mentioned, the gas turbine gains much more by increased inlet temperature than the steam turbine, the maximum inlet temperature being limited by the strength of the blades at this temperature. For this reason further development of the gas turbine is closely related to progress in metallurgy. During the war alloys were developed for aero engine exhaust turbines showing high strength at temperatures of 750 to 800 C (1382 to 1472 F), but unfortunately most of these alloys have only a short life and cannot yet be recommended for ordinary gas turbines.

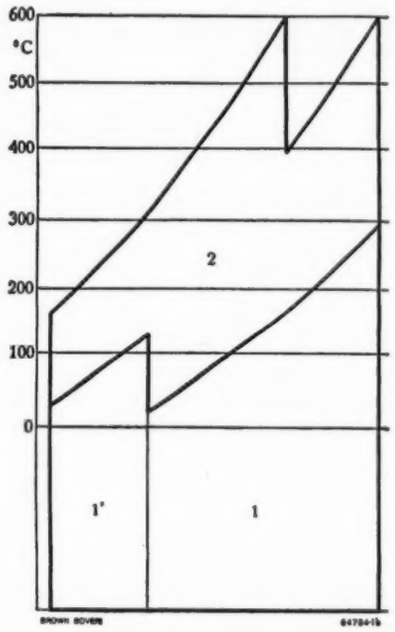

Fig. 6—Two-stage gas turbine cycle

As already pointed out, the efficiency of the gas turbine depends to a considerable extent on the amount one is prepared to invest in heat-exchangers. This can be determined by plotting fixed charges against running expenses.

From the various economic considerations involved it can be concluded that:

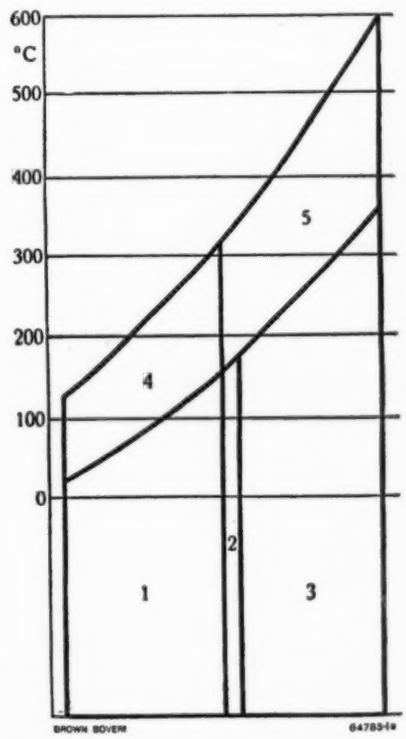

Fig. 7—Gas turbine cycle with heat-exchanger

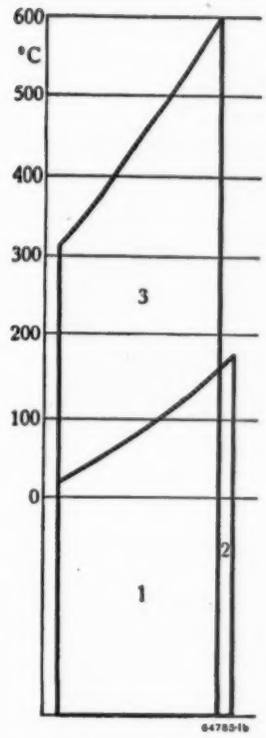

Fig. 8—Simplified diagram of gas turbine cycle with heat-exchanger

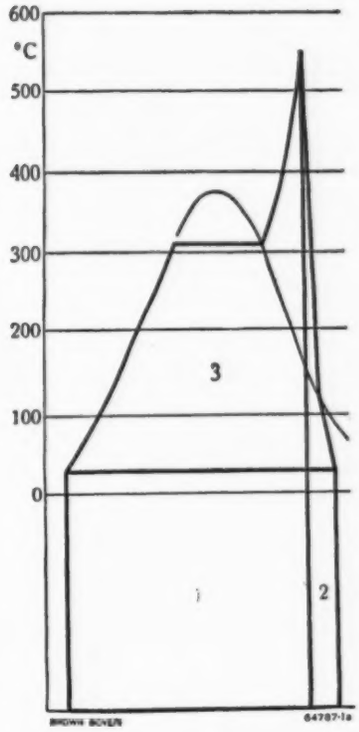

Fig. 9—Diagram of steam cycle including turbine losses

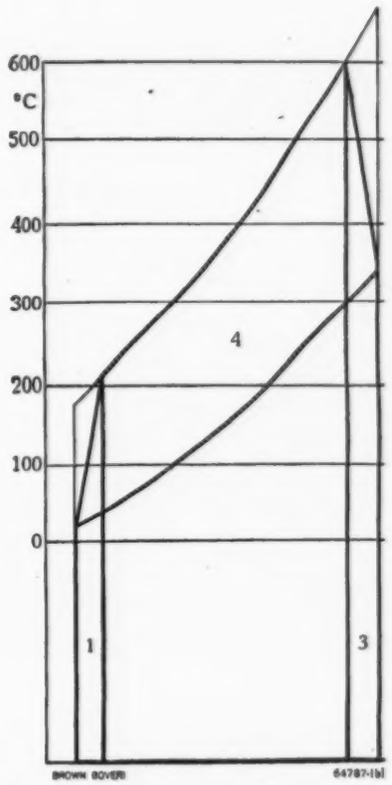

Fig. 10—Diagram of simple gas turbine cycle including turbine and compressor losses

1. For large power stations steam will continue to be the more economical.
2. Where oil or gas is available, the gas turbine may prove more economical in some cases in capacities up to 10,000 kw.
3. The economic prospects of the gas turbine increase with short running hours, cheap oil, or expensive coal, restricted space, scarcity of cooling water, and low atmospheric temperatures.

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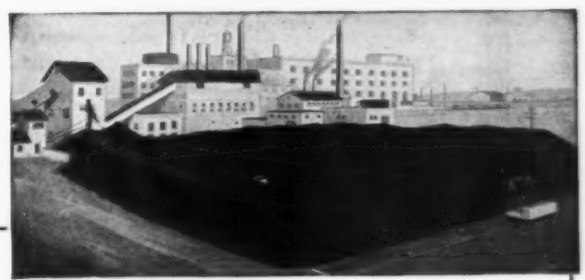

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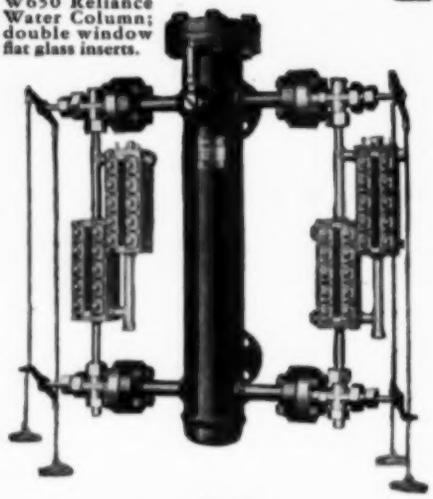

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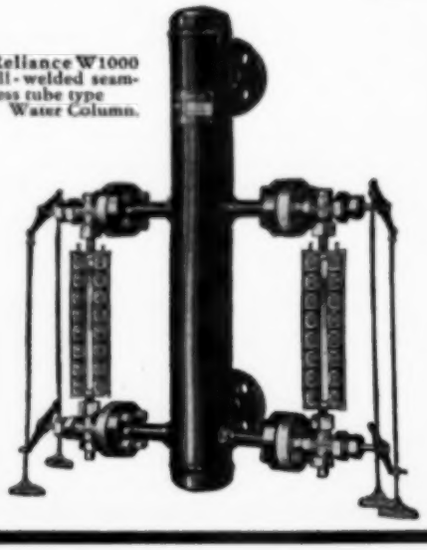

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Alaskan Town Has Unique Source of Power

Since the first of the year Anchorage, Alaska, has been receiving much needed additional power from a unique source, the 5400-kw G.E. marine turbine-electric power plant located in the stern half of a former government-owned tanker, the *S.S. Sacketts Harbor*, which previously had broken in two during heavy weather in the North Pacific. The bow section had been sunk by the Navy while the stern half proceeded to Adack, Alaska, under its own power. Later the city of Anchorage, urgently needing additional power generating capacity, leased the stern half containing the turbine-electric power plant from the Government and had it towed to Anchorage.

Although the electrical characteristics of the turbine-electric power plant fit well with the city's original electrical distribution system, several engineering problems had to be surmounted before the stern half could furnish power. The ship could not be anchored out in the inlet because of the swift water and tidal action. In winter ice cakes fill the Inlet, some as large as the ship. Also, the water in the Inlet is full of glacial silt and thus unfit for condenser cooling water.

A flat spot was dredged on the beach and the ship run aground at one of the high 33-ft tides. Once in position, the cargo tanks, holding three million gallons, were filled with fresh water, supplied by an 8-in. pipe line from the shore. Holes were cut in the bulkheads separating the tanks to permit circulation of the water. Pipes, 20 in. in diameter, were connected from the main condenser to the tanks. This system provided a cooling method as well as a means of retaining water ballast without danger of freezing during winter months when temperatures often reach 30 deg below zero.

At high tide, the ship stands in 25 ft of sea water; at low tide, it is high and dry. The operation of the power plant is independent of the sea water except at high tide when the outside water aids in cooling the fresh water in the cargo tanks, heated by accumulation from the main condenser. Operation of the power plant is little different from operation of the ship at sea.

Power supplied to the city's lines fits readily due to the turbine-electric power plant's 3-phase, 60-cycle, 2300-volt, unity-power factor rating. The turbine governor holds the frequency constant. A master clock is installed on the switchboard, necessitating only slight adjustments to the governor by the operator each hour to keep the electric clocks on the system on time. The voltage of the main generator is regulated by an amplidyne generator and regulator which holds very constant terminal voltage on the main generator. One of the two 525-kw auxiliary turbine-generator sets supplies power for the ship's auxiliary electrical requirements and excitation.

View of ship at low tide

Havana Power Station Put in Service

From July 12 to 19 the Illinois Power Company held open house to some six thousand visitors to mark the starting of its new Havana Power Station, located on the east bank of the Illinois River about a mile south of the city of Havana and about forty miles downstream from Peoria, Ill. An aerial view of the plant is shown on the cover of this issue.

This new station will serve the company's northern and central divisions through 138-kv transmission lines and will also connect by a 138-kv tie line with a proposed new plant to be located at Wood River, Ill., for supplying the southern division of the system.

It is designed for an ultimate capacity of 200,000 kw, consisting of five 40,000-kw turbine-generators supplied with steam at 850 psi, 900 F by 7 CE 285,000-lb-per-hr steam generating units. The initial section consists of two turbine-generators and three steam generating units. The second section, to have three turbine-generators and four additional steam generating units, is now under construction under a schedule calling for operation of Unit No. 3 in October 1948 and the remaining units in April 1950.

The steam generating units are of the three-drum type with completely water-cooled hopper-bottom furnaces. They are served by C-E Raymond bowl mills and have vertically adjustable tangential burners which are supplemented with bypass dampers for superheat control. Tubular air preheaters are incorporated in the units. Provision is made for receiving coal by water, rail or truck, although it is expected that the bulk of the coal requirements will be delivered by barge from the Fulton County fields on the west side of the Illinois River about fifteen miles upstream from the plant.

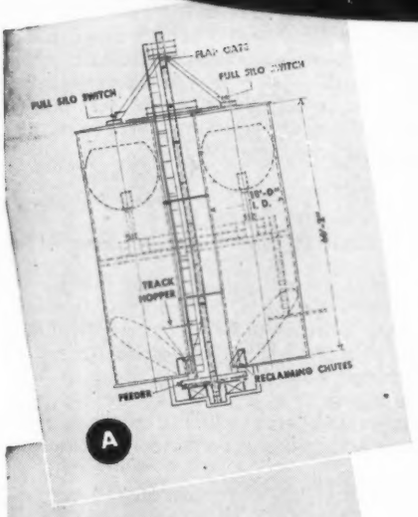
British Power Station Practice

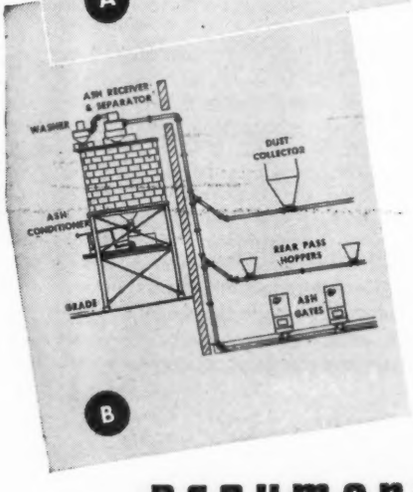
In a recent paper before the Incorporated Municipal Electrical Association, reported in *Engineering* of July 25, F. W. Lawton gave some interesting figures on the growth of electricity demand and supply in Britain from 1938 to 1945, discussed current practice in design, and cited the performance of certain well-known stations.

During this seven-year period the national peak demand increased by 33 per cent, reaching nearly 9,000,000 kw; the electrical consumption rose 60 per cent; and the power factor increased from 36.8 to 43.8 per cent. Notwithstanding the cessation of hostilities, the higher load factor is being maintained. However, despite the installation of much new efficient equipment, the average station efficiency has remained about the same, due to deterioration in the calorific value of the coal supplied and to the existence of much obsolete equipment remaining in service.

Large Advances in Fuel and Construction Costs

Since 1938 the average cost of coal has increased by 114 per cent and the average cost of new plants by 87½ per cent, the present cost per kilowatt being about 40£ ($160). The annual tonnage of coal burned in pulverized form has more than doubled, to 4,401,000 tons and that burned on stokers has increased by nearly 50 per cent, to 18,104,000 tons.





COAL HANDLING

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The Beaumont "Vac-Veyor" system offers the most direct and economical method for removal of ashes, siftings, soot and dust. They are vacuum conveyed through a pipe from their source to an ash receiver and separator—then into the silo where they remain until final disposal.

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Designers Manufacturers Erectors BULK MATERIAL HANDLING SYSTEM

As to new plant construction, it is estimated that during the next five years boiler plant capacity of over 72 million pounds of steam per hour will be added, of which two-thirds will be fired with pulverized coal.

With regard to pulverized-coal-fired boilers, it is significant that the majority are of the dry hopper-bottom type. Only one slagging-bottom furnace is now under construction. Observing that since 1938 practically no superposed plants have been installed, the author contends that they can be justified only if the load factor is over 60 per cent.

Load Factors Govern Steam Conditions

With fuel at 55 s ($11) per ton and considering the present plant construction costs, steam conditions of 900 F and 900 psi can be justified at load factors exceeding 40 per cent. With higher steam conditions, higher load factors are believed necessary to show financial gains. Of nearly six million kilowatts new capacity to be installed during the next five years, approximately half will be operated at 600 psi and 37.5 per cent at 900 psi. Turbine-generators of 50,000 kw and 60,000 kw are becoming quite common and in these sizes hydrogen cooling appears justified when the load factor exceeds 40 per cent.

Although the average overall thermal efficiency of all selected stations supplying the Grid is about 21 per cent, much higher efficiencies are being obtained at certain riverside stations, notably Battersea with 28.82 per cent, and Dunstan with 27.85 per cent. Hams Hall, a cooling-tower station, reports 27.3 per cent overall efficiency.

Lignite One-Third of U. S. Fuel Supplies

Testifying recently before a subcommittee of the House Committee on Public Lands, in a hearing on the bill to provide funds for the establishment and maintenance of a research laboratory in the North Dakota lignite-consuming region, Dr. A. C. Fieldner and Dr. L. C. McCabe of the U. S. Bureau of Mines stated that lignite constitutes nearly one-third of the nation's solid fuel reserves. Despite this, American research for full industrial utilization of this source of energy has been much less extensive than that in Germany with comparable fuel.

Pointing out that the development of uses for lignite in this country would conserve our high-rank coal and would further industrial development of the Great Plains states, Dr. Fieldner declared that North Dakota has more than 60 per cent of the known reserves of lignite in the United States. The total tonnage of this fuel is estimated by the Geological Survey at 939 billion tons, of which 600 billion tons are in North Dakota and 315 billion tons are in eastern Montana. These reserves, together with the small amount in South Dakota, represent 98 per cent of this country's lignite reserves.

The total lignite deposits amount to 32 per cent of our unmined fuel tonnage or

19 per cent of our mineral fuel reserves other than fissionable materials, Dr. Fieldner reported. Lignite usually has a heating value of less than 7000 B.t.u. per pound which is approximately half that of our best bituminous coal. As mined, it generally contains from 30 to 40 per cent moisture and when dried in air it slacks and ignites, making storage for long periods or shipment to distant points of consumption difficult.

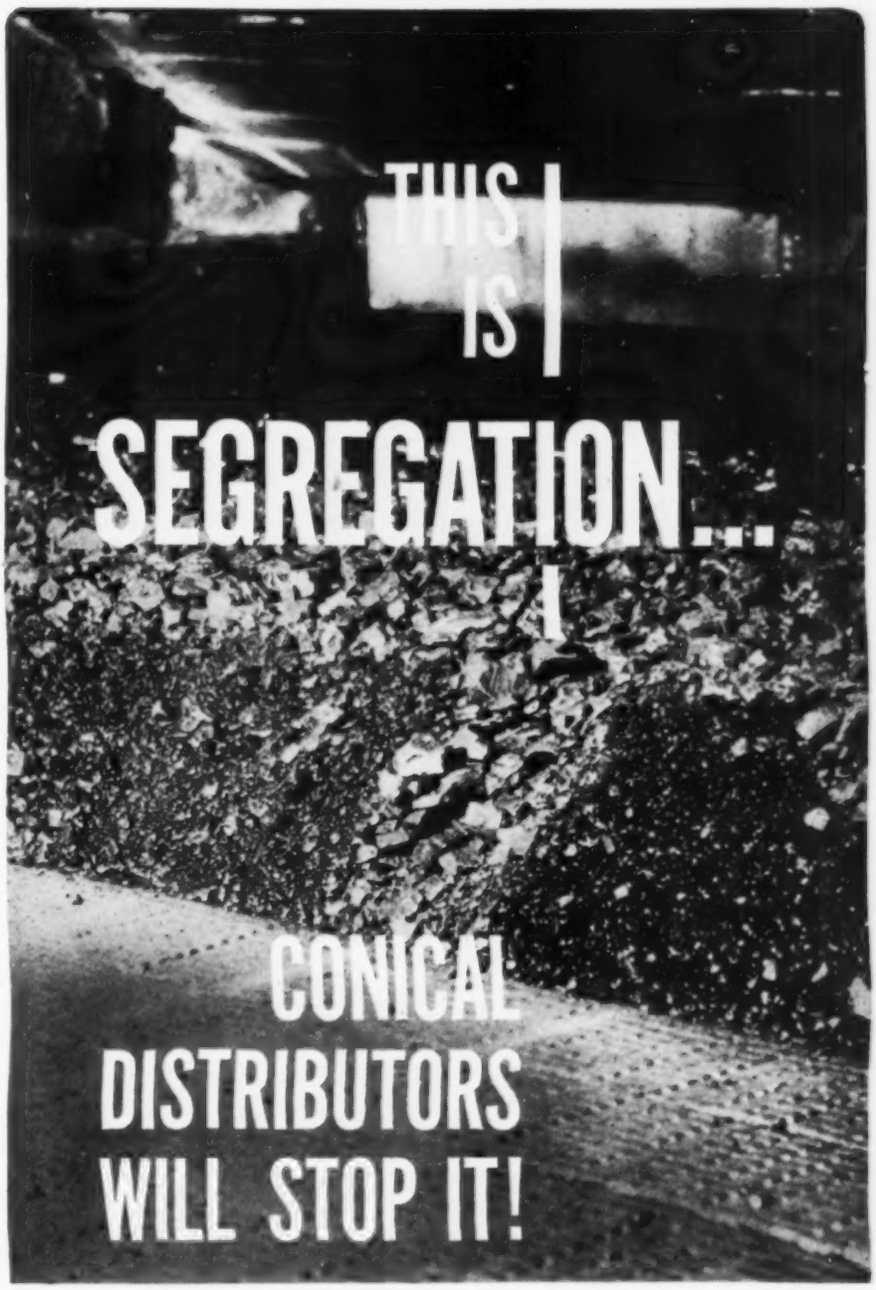
In attempting to overcome some of the difficulties of using the fuel, the Bureau of Mines in cooperation with the University of North Dakota and the Minnesota-North Dakota Resources Development Commission investigated a feasible drying process that prevents slacking and at the same time raises the heating value from 7000 to 10,000 B.t.u. per pound. Further research on this process is necessary, however, to expand the marketability of lignite.

Additional research also is needed on other possible uses suggested by Dr. Fieldner, such as the raw material source for the commercial production of synthetic ammonia for fertilizers and explosives, in the production of methanol for plastics, solvents, and chemical uses, in making synthetic gasoline, diesel oil, and fuel oil, and for the reduction of iron ores.

According to Dr. McCabe, much of Germany's industrialization has been developed around German brown coal, a lignitic coal somewhat similar in character to deposits in this country. Less than a decade ago 50 per cent of the brown coal was used to generate electric power at the mine site and 60 per cent of all power was generated in this way. The highly developed briquetting industry used 23 per cent of the lignite tonnage, and during the war briquets were the only solid fuel available to most German households. Briquets also were shipped to France, Belgium, and the Netherlands to supply the domestic market while the metallurgical and by-product coals of these countries were drawn off to supply the German war industry. Brown coal also was an important raw material source in the production of synthetic gasoline and fuel oil before and during the war, 21 per cent of the production being used for this purpose in 1938. The same year, chemical and general industry consumed about 6 per cent of the production.

Lubricants and margarines were produced from the lignites of Western Germany and the brown-coal mines of Saxony yielded a high melting point wax known as Montan wax. Prior to the war, the United States imported 8 million pounds of this wax annually for use in the insulation of electric wiring, phonograph records, shoe polish, and floor waxes. The cost of the wax in the raw state delivered in the United States was about 60 cents a pound.

Seeking an alternate source for the German waxes which are now in the Russian Zone, the Bureau of Mines has conducted a limited amount of analysis on lignites in this country and those from Arkansas and California have shown from 10 to 13 per cent of recoverable wax. To experiment further on these coals, a small recovery plant has been built in Arkansas, Dr. McCabe reported.



In order to obtain the above photograph, coal was run onto a chain grate stoker and then the coal in the foreground was carefully removed. Photograph is taken inside the boiler looking toward the stoker hopper.

Note that the coarse streak of coal shows a definite separation or *segregation* from the finer coal on each side. Where this condition exists fuel is wasted, boiler efficiency is materially reduced and arches require far too frequent attention.

CONICAL Non-Segregating Coal Distributors deliver coarse and fine coal in uniform mixture across the stoker hopper. Combustion is uniform —no "hot spots" or smothered areas in the fuel bed. The result is higher boiler efficiency, lower fuel consumption and less stoker arch maintenance.

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For further information write for Catalog I-137-C

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Electric Output Continues Upward

Output of electric utility plants continues to increase steadily, a new August record having been reached with 4,805,740,000 kw hr for the week ending August second. This figure was 10.5 per cent over that for the corresponding week last year and 8.4 per cent over that of 1945. The greatest percentage increase was in the Pacific coast region.

Total revised figures for July have not yet been made available by the Federal Power Commission but figures for June showed a total output of 19,917,000,000 kw hr, representing a gain of 14.3 per cent over June 1946, and a June peak of 41,699,000 kw. This latter was 12.3 per cent higher than June of last year and exceeded the wartime peak of 38,252,630 which was reached in January 1945. The all-time high was attained in December 1946 with a peak of 43,173,808 kw.

The fuel consumption of electric utility plants in June was 6,631,585 tons of coal, 3,273,323 bbl of fuel oil and 33,078,037 mcf of gas. Hydro accounted for approximately one-third the total output, a percentage that has held fairly constant over a considerable number of years.

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Fig. 21 Fig. 22

Fig. 12

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Fig. 13
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NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Electric Turbine Governer

General Electric Co. describes in publication GEA-4764 an electric governor of new design providing accurate control over a wide speed range for G-E Type DE turbines.

Salient features of the governor's components are shown in cutaway photographs of the unit's interior. A schematic diagram illustrates the interrelationship of speed sensitive element, control panel and relaying mechanism. With constant steam and load conditions speed variations of plus or minus one-tenth of one per cent or less are claimed.

Engineering Data Booklet

The Leslie Co., manufacturers of pressure and temperature regulators and controllers, strainers and whistles, has issued a new 12-page bulletin, No. 467, "Engineering Data and Reference Tables." The tables contained should provide useful information for laying out piping and associated equipment.

Feedwater Heaters

Cochrane Corp. has just issued Publication 4091 which describes three lines of open heaters for direct-contact heating of boiler feed and industrial process waters using exhaust or live steam. This 24-page bulletin discusses the advantages of direct-contact open heaters and gives the characteristics of different designs. Also given are flow diagrams, installation photographs and a descripton of accessories.

Feedwater Regulators

Bulletin No. 471 by Northern Equipment Co. describes the Copes Type P Regulator for remote boiler feedwater control. This regulator, originally developed to meet wartime needs of boilers on ships, is available as a single element unit, for simple level control, or as a two-element Copes Flowmatic Control. Since it is air operated, it permits placing the feedwater control valve at any location with respect to the thermostat, making this type of control easily adapted to any piping layout or operating preference. Both the single- and two-element controls are described in detail and illustrated diagrammatically. Also included is a list of specifications.

Also recently released by Northern Equipment Co. is Bulletin No. 429B describing the Copes Flowmatic Regulator. The bulletin contains installation views, performance curves and a schematic drawing showing the operating principle of the Copes Flowmatic Regulator using a direct-operated valve. A list of specifications for this regulator is included.

Flow Measurement

Catalog Section 25-E, recently issued by Fischer & Porter Co., describes the Series 700 Flowrator. This 24-page booklet illustrates and describes the construction of several types used for measuring flow of liquids and vapors, including a new bead-guide metering tube for use with opaque fluids. Also included are descriptions of portable flowrator test kits, flow alarms and remote indicating, recording, controlling and proportioning instruments.

Insulation

Geo. P. Reintjes Company announces suspended wall locking for water walls which is described in Bulletin B-547. The bulletin is well illustrated showing details of instruction particularly of the locking device for holding the insulation to the tubes. The factors in selection of sectionally supported walls are given. Additional information may be found in Catalog C-46.

A new 40-page catalog on plastic firebrick has been issued by the Laclede-Christy Clay Products Co. This well-prepared catalog is profusely illustrated. Included are close-ups of both metal and refractory anchors and how they are used in installing walls. Typical applications to boiler furnace constructions are given. A section is devoted to plastic suspended arches while another illustrates and describes several of the Laclede specialties such as doors and refractory materials. Engineering tables and data on Laclede products complete the catalog.

Instruments and Meters

Bailey Meter Co. has issued Bulletin 231 describing their line of electronic instruments. Combinations of standard indicating, recording, integrating and controlling instruments are available and are adaptable to the measurement of temperature, pressure or vacuum, fluid flow, liquid level, speed or position, smoke density and per cent oxygen and combustibles. Included in the bulletin are descriptions of the various units and drawings of several measuring circuits.

Bulletin 233 by Bailey Meter Co. describes their new electronically operated area meter for flow measurements. It consists of a transmitter installed in a pipe line like a valve and an Electronic Type Receiver which may be located at practically any distance from the transmitter. Accurate measurement of the flow of more viscous liquids such as tar, chemicals, black liquor, distillates and refrigerants, as well as freer flowing liquids is claimed.

Mechanical Drive Turbines

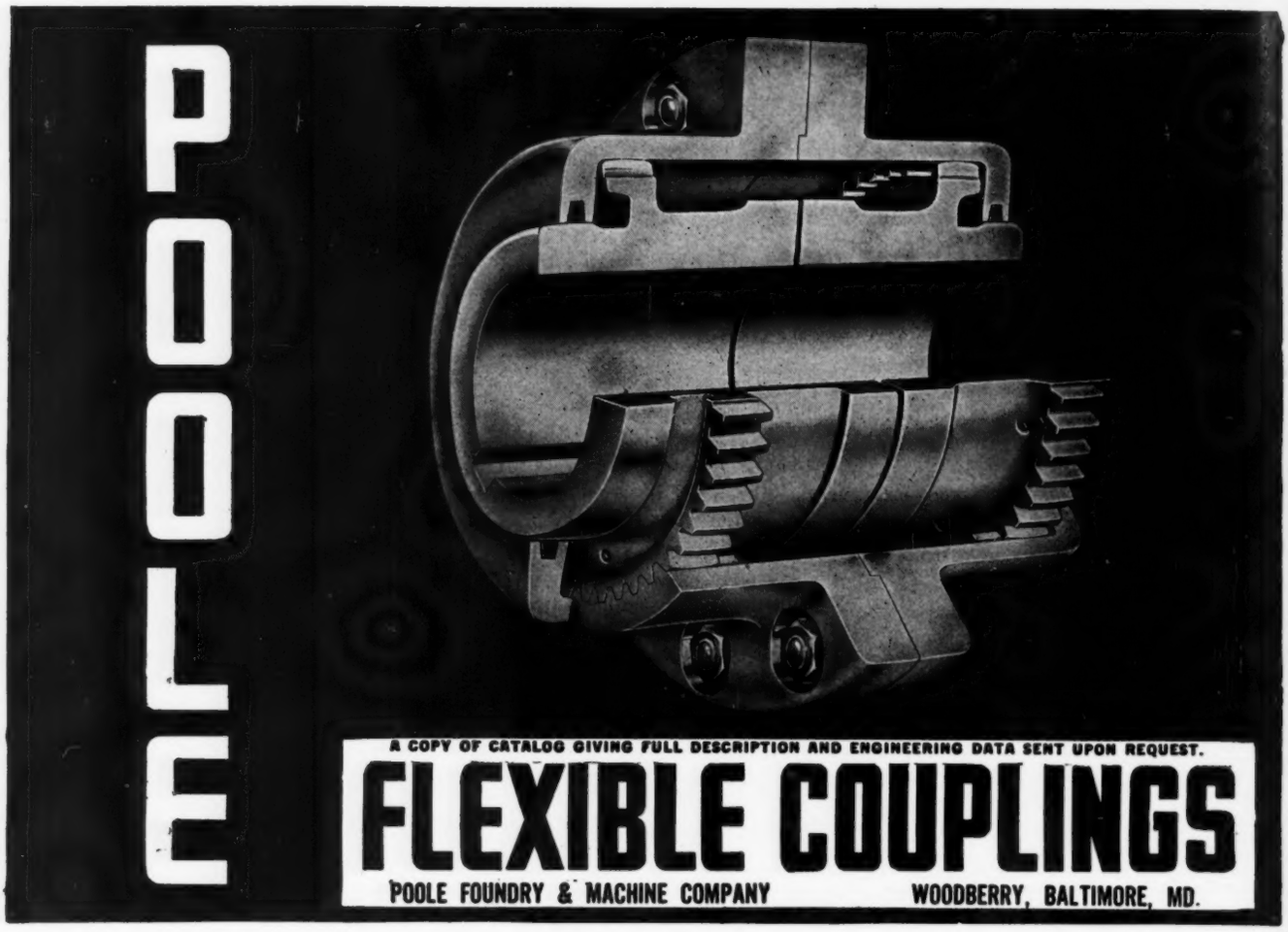
The Elliott Co. has just issued Bulletin H-16 giving a brief description of its new YR mechanical drive turbine. Included in the bulletin is a brief history of the development of mechanical drive turbines. It covers both general and material specifications of this new turbine and shows a detailed section through the unit with an explanation of the various features. Also covered are ten modifications to standard turbines and the six types of governors available.

Type E Stoker

Combustion Engineering Co., Inc., has issued Catalog No. E-12 describing its Type E single-retort underfeed stoker. This stoker, which burns caking or non-caking bituminous coals and waste fuels such as wood refuse in combination with coal, is usually applied to boilers ranging from 150 to 600 rated boiler horsepower, providing steam capacity up to 50,000 lb per hr. The catalog summarizes the features of the stoker and discusses construction, installation and operation. Also shown are cross-sectional and installation views.

Water Softeners

The essential function of a hot process water conditioning system is explained and diagrammed in a new 12-page bulletin (28B6611) recently issued by Allis-Chalmers. Description of the equipment and an explanation of what it is designed to do, together with the mechanism of its operations, are included. Functions of various equipment items such as the reaction and sedimentation tank, spray heater, vent condenser, vacuum breaker and chemical feeding equipment are given. Also covered are condensate and treated water storage, phosphate softening and silica removal.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